Progress Review for the Projects:

- **Program to Develop Advances in Combined Heat and Power Systems**

- **Enhancing the Operation of Highly Varying Industrial Loads to Increase Electric Reliability, Quality, and Economics**

NiSource Energy Technologies
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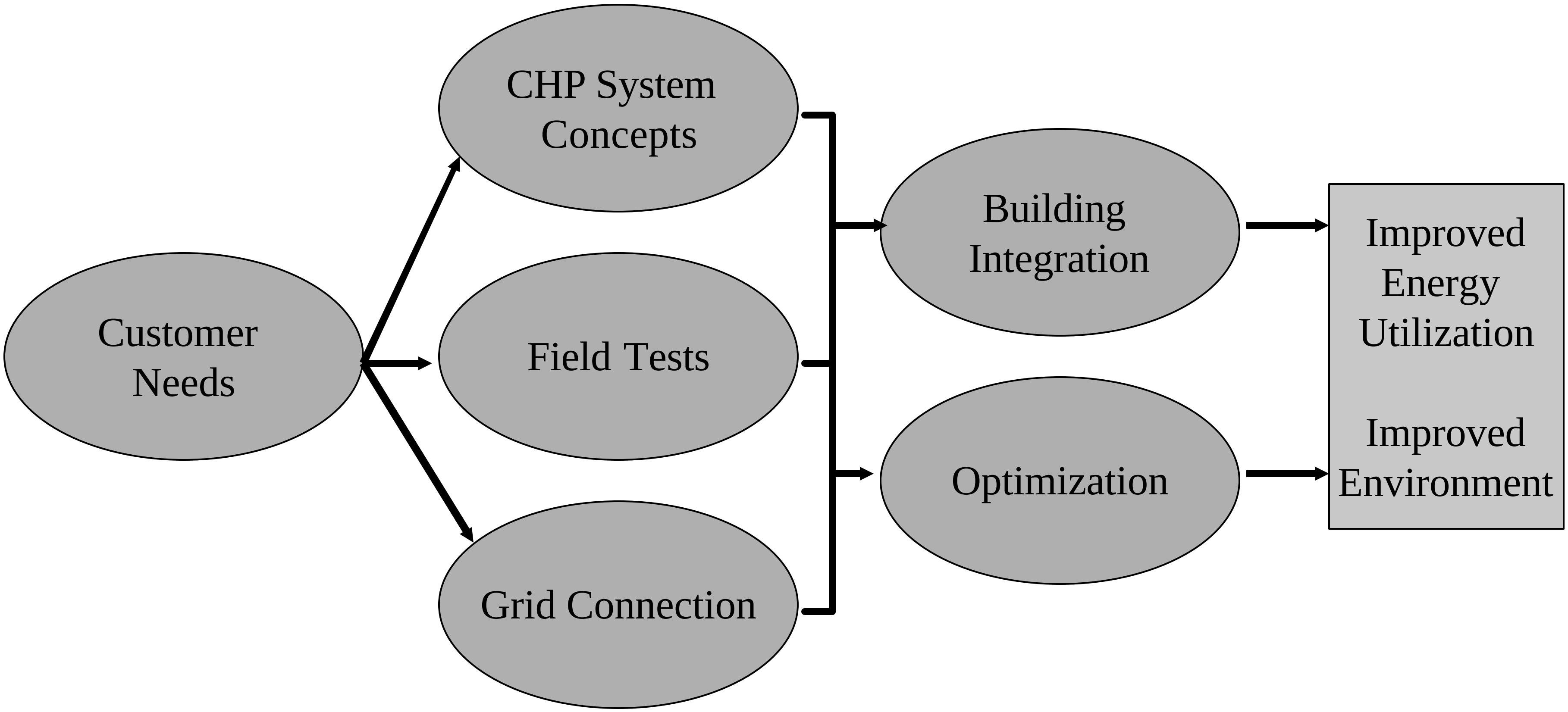
Program to Develop Advances in Combined Heat and Power Systems

Basic Program Outline

- Three-phase, multi-year research and development effort to advance distributed power development, deployment, and integration
- Develop, test, and optimize several (electric/natural gas/ renewable energy) stand-alone distributed power systems
- Develop and initiate laboratory and field tests, methodologies, controls (including command, communications, monitoring, efficiency, and heat rate)
- Fully document, publish, and otherwise disseminate (through regional/national speeches, reports, and conferences) non-proprietary results and conclusions for maximum national replicability

Project Task Flow



Phase I - (First Year) - Refine Stand Alone Systems

- **NiSource Energy Technologies will develop, demonstrate, validate, and optimize small stand-alone distributed power technologies with the goal of exceeding current reliability, availability, efficiency, and emission goals.**

Phase 1 Tasks

- **Task 1: Interconnection Issues**
- **Task 2: Zoning and Permitting of Distributed Generation**
- **Task 3: System Integration and Performance**

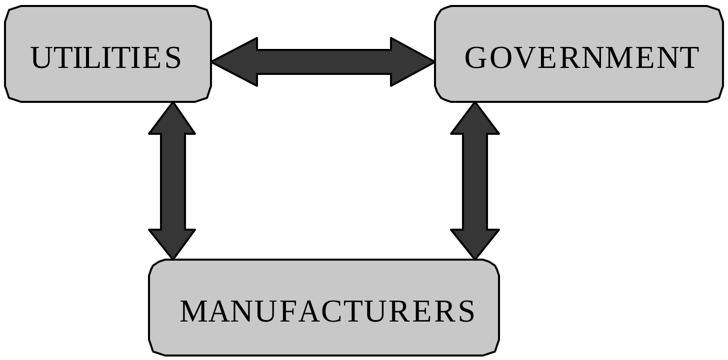
Phase 1 Task 1

- ***<u>Task 1: Interconnection Issues</u>***
  - **Identify and detail the interconnection issues for CHP**
    - **Determine state of the art**
    - **Describe the characteristics of distribution systems**
    - **Describe physical interconnections with the grid and associated issues**
    - **Identify required interconnection tests**
    - **Determine the costs and delays associated with interconnection issues**
    - **Determine the impact on utility rates, fees, business, practices, utility experience and regulatory practices on the cost of interconnection.**

Phase 1 Task 1

- The level of development of interconnection technology attained is directly proportional to the amount of initiative, effort, and cooperation that the involved entities--utilities, manufacturers, and governmental bodies--are willing to put forth.
- We have performed a search yielding massive amounts of data in regards to what these groups are doing regarding interconnection practices and procedures.

Interaction Between Standards Contributing Organizations



Survey Strategy

- **Survey of utility requirements on key technical issues.**
  - Contacted more than 100 major investor-owned utilities from across the nation. From each of these utilities, requested documentation containing established technical interconnection requirements for a customer-generator wishing to operate in parallel with the utility's electrical distribution system. 17 of the contacted utilities replied.

  - Analyzed data according to generator classification, disconnect switch requirements, applicable codes and standards, protective relaying specifications, isolation transformer requirements, and power quality requirements.

A comparison of manual disconnect requirements among surveyed utilities.

Utility	Visible Break	Load Break Capability	Utility Accessible	Utility Lockable	Clear Labeling of Disconnect
1	Ö*	Ö	Ö	Ö	Ö
2	**NS**	Ö	Ö	Ö**	**NS**
3	Ö	**NS**	Ö	Ö	Ö
4	Ö	**NS**	Ö	Ö	**NS**
5	Ö	Ö	Ö	Ö	**NS**
6	Ö	Ö	Ö	Ö***	**NS**
7	Ö	**NS**	Ö	Ö	**NS**
8	**NS**	**NS**	Ö	Ö	**NS**
9	Ö	Ö	Ö	Ö**	Ö
10	Ö	**NS**	Ö	Ö**	Ö
11	Ö	**NS**	Ö	Ö**	**NS**
12	**NS**	**NS**	Ö	Ö	**NS**
13	**NS**	**NS**	Ö	**NS**	**NS**
14	Ö	**NS**	Ö	Ö	**NS**
15	Ö	**NS**	Ö	Ö	**NS**
16	Ö	Ö	Ö	Ö	**NS**
17	Ö	Ö	Ö	Ö**	Ö

*Definition of “visibly open” requires that the switch blades, jaws, and air gap between them be clearly visible in OPEN position. View of these components can not be obscured by the arc shield or switch case. It is uncertain whether such switches are readily available.

**Utility lockable in OPEN position only.

***Utility lockable in OPEN and CLOSED positions.

√ = Required by standard.

NS = Not Specified in standard.

Utility 13 only calls for intertie circuit breaker device, on generator side.

A comparison of power quality specifications among surveyed utilities.

Utility	Comments
1	Must satisfy IEEE 519-1992, at minimum. Allowable power factor- 90% lagging, but not leading; maximum allowable current imbalance is 10%; must limit harmonic content, power fluctuations; voltage flicker not to exceed utility standard.
2	Standard includes no specific information regarding power quality requirements.
3	Includes very general section on power quality requirements addressing the issues of abnormal voltages, frequencies, and harmonics, per ANSI/IEEE 519-1992; sets specific limit of 3% for voltage unbalance at the point of common coupling.
4	Customer must conform to power quality requirements of IEEE 1547 for the limits of DC injection, voltage flicker, harmonics (ANSI/IEEE 519-1992 also referenced), immunity protection, and surge capability. Minimum power factor is 0.9.
5	Standard contains only a general reference to the idea of power quality- nothing specific.
6	Standard states that equipment is to conform to ANSI/IEEE 519-1992.
7	Voltage to be within 6% of nominal level; 2% maximum voltage flicker; 'soft' load transfer, if necessary; 60 Hz system frequency restoration contribution; power factor to be 0.95 leading-0.95 lagging; harmonic distortion per IEEE 519-1992.
8	Standard contains only general references to the concept of power quality- including abnormal voltage, abnormal frequency, and voltage flicker.
9	Harmonic limits and voltage fluctuations per IEEE 519-1992; power factor to be from 0.9 leading to 0.9 lagging.
10	Power quality standard addresses concerns in the areas of voltage (onsite generation should be operated at +5/-10% of nominal voltage at PCC), power factor (varies with customer rate class), harmonic voltage limits, and harmonic current limits (harmonic limits to be in adherence to ANSI/IEEE 519-1992).
11	Power quality-related items addressed in this standard are normal voltage operating range (106-132V on 120V base), voltage flicker (limits as defined in ANSI/IEEE 519-1992), frequency (58.0/59.3-60.5Hz), harmonics (in compliance with ANSI/IEEE 519-1992), DC injection, and power factor.
12	Contains generic reference to standard waveform, harmonic distortion, and voltage limits; installation must meet applicable standards in all of these areas.
13	Maximum 5% voltage waveform distortion; 1% limit on phase unbalance; total voltage harmonic distortion not to exceed 5% (3% limit for single harmonic), per IEEE 519-1992; power factor of generator must be from 0.85 lagging to unity.
14	Voltage to be within 6% of nominal level; 2% maximum voltage flicker; operating frequency not to deviate more than 0.5 Hz from 60 Hz base; power factor ranging from 0.85 leading-0.85 lagging; harmonic content based on IEEE 519-1992.
15	Contains general reference to non-sinusoidal waveform and voltage fluctuation per IEEE 519-1992, 929-2000, and 84; generator to be capable of producing 0.85 power factor.
16	Standard addresses voltage limits, but not specifically; power factor to be 0.90 lagging to 0.95 leading at normal voltages; harmonic content to satisfy requirements of IEEE 519-1992.
17	Issues addressed include voltage limits and voltage flicker; frequency control (0.5 Hz maximum deviation on a 60 Hz base); power factor of 90% lagging to 90% leading; harmonic distortion limits per IEEE 519-1992; fault current levels.

Preliminary Conclusions

- **There are clearly many opinions by many different groups as to the need for and applicability of CHP energy sources for a diversity of different purposes.**
- **In general, most utilities don't consider CHP as a major electric system consideration in the near or long term.**
- **The volatility in the CHP device market makes it difficult to plan or tie down even preliminary details.**
- **Local Building inspectors are often not greatly concerned with, if they have even heard of, CHP.**
  - Generally they look to NEC as their principal guide.
- **Standards such as IEEE will provide much benefit, but they need to be supplemented for general use. Locally there is a lack of understanding as to how it will all fit together and what it will actually mean to operations.**
  - DG Road Show is an excellent start.
- **The benefits of CHP need to be made clear to the major players in a way that a sense of common benefit and direction can be formulated. CHP can provide at least a partial solution to problems associated with insufficient electric transmission capabilities and constraints.**

Additional Results

- ***Please see final report for complete details.***
  - Too voluminous to list here

Phase 1 Task 2

- ***<u>Task 2: Zoning and Permitting of Distributed Generation</u>***
  - **Identify zoning and permitting requirements and assess the associated costs for installing DP systems within the NiSource service area**

Phase 1 Task 2

- **Building codes generally adopted on a state-by-state basis. Usually will adopt one of the national codes. Then will adopt amendments to bring into compliance with the states' laws.**
- **The National Electric Code is the only national code that is used throughout the US. In its latest form does not directly address DG.**

Phase 1 Task 2

State	Adopted State Building Code	DG Amendments
Indiana	Unified Building Code	No
Kentucky	BOCCA	No
Maine	None	No
Maryland	International Building Code	No
Massachusetts	BOCCA	No
New Hampshire	None	No
Ohio	BOCCA	Yes
Pennsylvania	Title 34 Pennsylvania's Fire & Panic Code	No
Virginia	BOCCA	No

Phase 1 Task 2

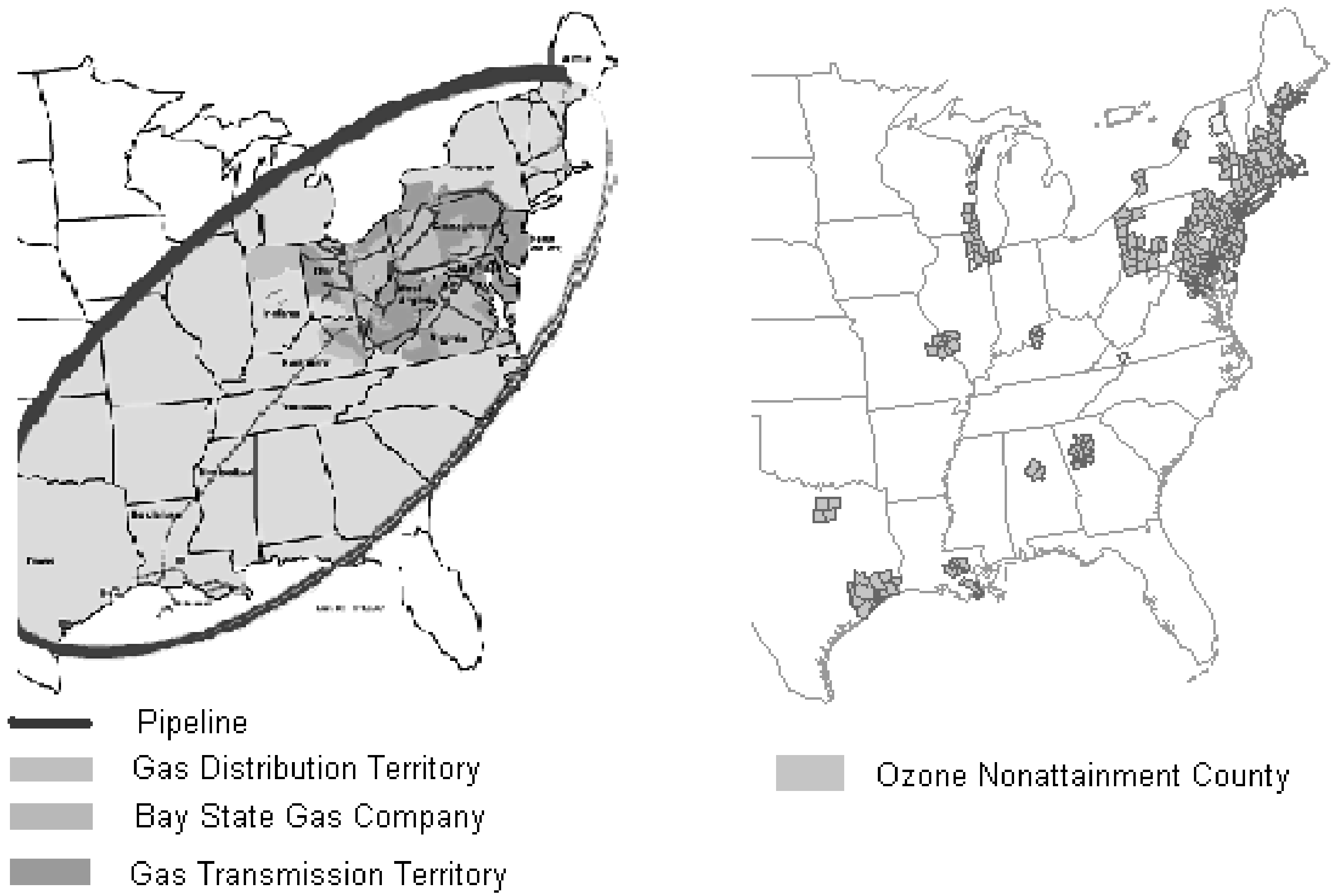


Figure 1. NiSource Gas Service Territories and Ozone Nonattainment Areas

Phase 1 Task 2

State	Exemption Levels (emissions less than the following amounts)								Special Exemptions
	NO_x	CO	VOC	PM_{10}	SO_2	Pb	Single HAP	Total HAP	
Kentucky (1)	5 tpy	5 tpy	5 tpy	5 tpy	5 tpy		2 tpy	5 tpy	
Indiana (1)	10 tpy	25 tpy	10 tpy	5 tpy	10 tpy				
Ohio (1)	10 lb per 24	10 lb per 24	10 lb per 24	10 lb per 24	10 lb per 24		1 tpy		Natural gas combustion less than 10 MMBtu/hr.
Virginia (1)	40 tpy	100 tpy	25 tpy	15 tpy	40 tpy	0.6 tpy			Gaseous fuel combustion less than
Pennsylvania (1)									Natural gas combustion less than 10 MMBtu/hr.
Maryland (1)									Natural gas combustion less than 1 MMBtu/hr.
Massachusetts (1)									Combined combustion turbine installation less
New Hampshire (1)									Natural gas combustion less than 10 MMBtu/hr.
Maine (1)									Natural gas combustion less than 10 MMBtu/hr.
West Virginia (2)	10 tpy	10 tpy	10 tpy	10 tpy	10 tpy			5 tpy	No other requirements.
Delaware (2)	0.2 lb/day	0.2 lb/day	0.2 lb/day	0.2 lb/day	0.2 lb/day	0.2 lb/day			
New Jersey (2)									Gaseous fuel combustion less than 1
New York (2)									Natural gas combustion less than 10 MMBtu/hr.
Louisiana (2)	5 tpy	5 tpy	5 tpy	5 tpy	5 tpy				Generally must obtain exemption letter.
Mississippi (2)	10 tpy	10 tpy	10 tpy	10 tpy	10 tpy		1 tpy	2.5 tpy	
Tennessee (2)									Gaseous fuel combustion less than 10 MMBtu/hr.

Phase 1 Task 2

State	30 kW Exempt	200 kW Exempt	Requirements
Kentucky [1]	Yes	Yes	
Indiana [1]	Yes	Yes	
Ohio [1]	Yes	Likely[5]	
Virginia [1]	Yes	Yes	
Pennsylvania [1]	Yes	Yes	
Maryland [1]	Yes	No	More than 2 MTs at a site will
Massachusetts [1]	Yes	No	More than 6 MTs at a site will
New Hampshire [1]	Yes	Yes	
Maine [1]	Yes	Yes	
West Virginia [2]	Yes	Yes	Assumes no other local
Delaware [2]	No	No	State permitting required.
New Jersey [2]	Yes	No	More than 2 MTs at a site will
New York [2]	Yes	Yes	
Louisiana [2]	Yes	Yes	Generally must obtain an
Mississippi [2]	Yes	Yes	
Tennessee [2]	Yes	Yes	

1) NiSource Natural gas transmission and distribution territory.
(2) NiSource Natural gas transmission territory.
(3) Assumes maximum heat input of 0.43 MMBtu/hr.
(4) Assumes maximum heat input of 3.44 MMBtu/hr.
(5) Ohio exempts natural gas combustion units less than 10 MMBtu/hr. However, NO_x emissions potentially exceed the 10 lb per 24 hour exemption level creating a conflict in the regulations. A region specific determination would have to be made by the controlling Ohio agency.

Additional Results

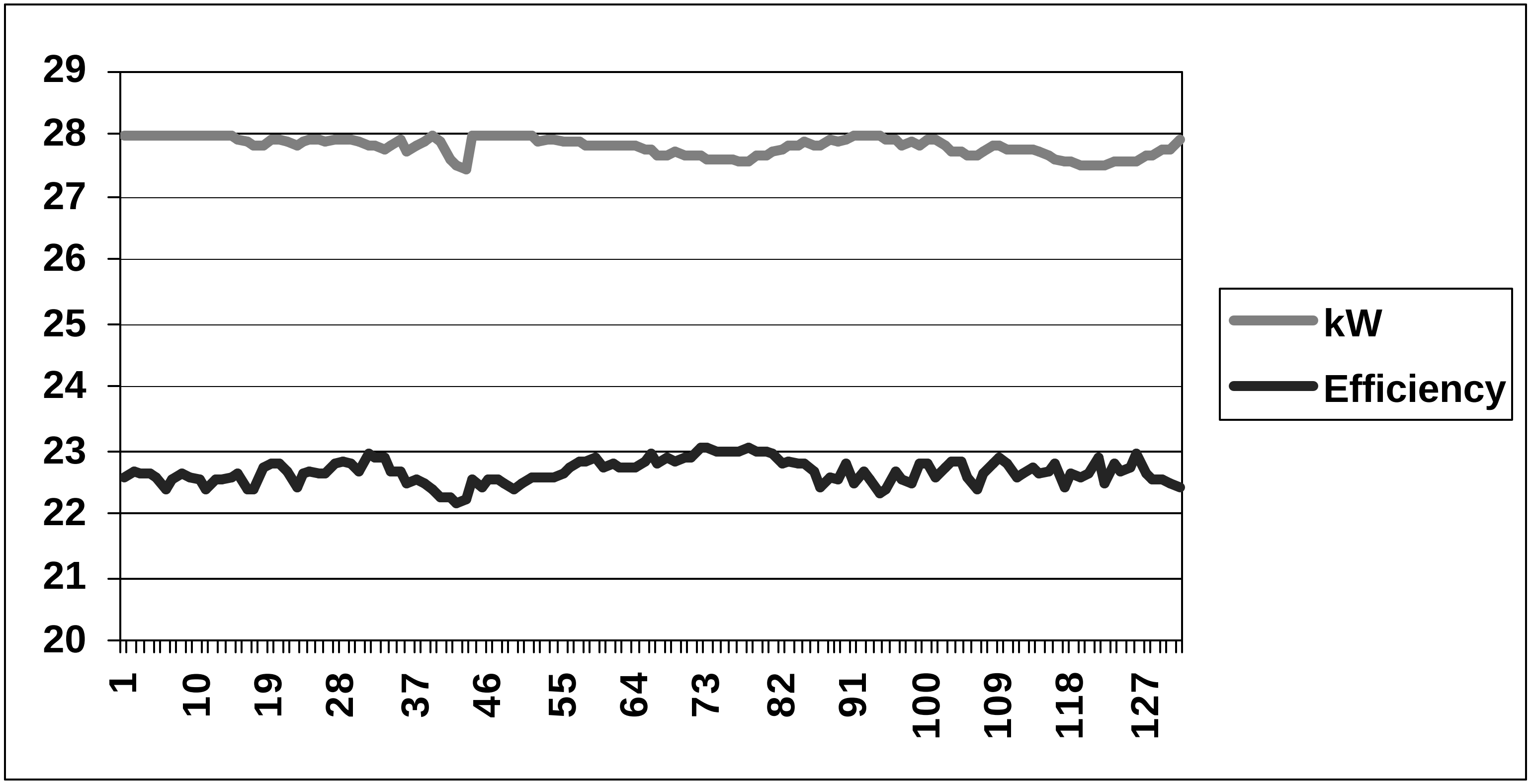
- ***Please see final report for complete details.***
  - Too voluminous to list here

Phase 1 Task 3

- ***<u>Task 3: System Integration and Performance</u>***
  - **Gather data to assess the validity of models through field testing**
    - **Benchmark the performance of 2 DG systems, including reliability, emissions, efficiency, etc.**
    - **Monitor the performance of power electronics systems**
    - **Evaluate performance relative to the grid**
    - **Definition of tracking and control systems**

Phase 1 Task 3
Test System 1

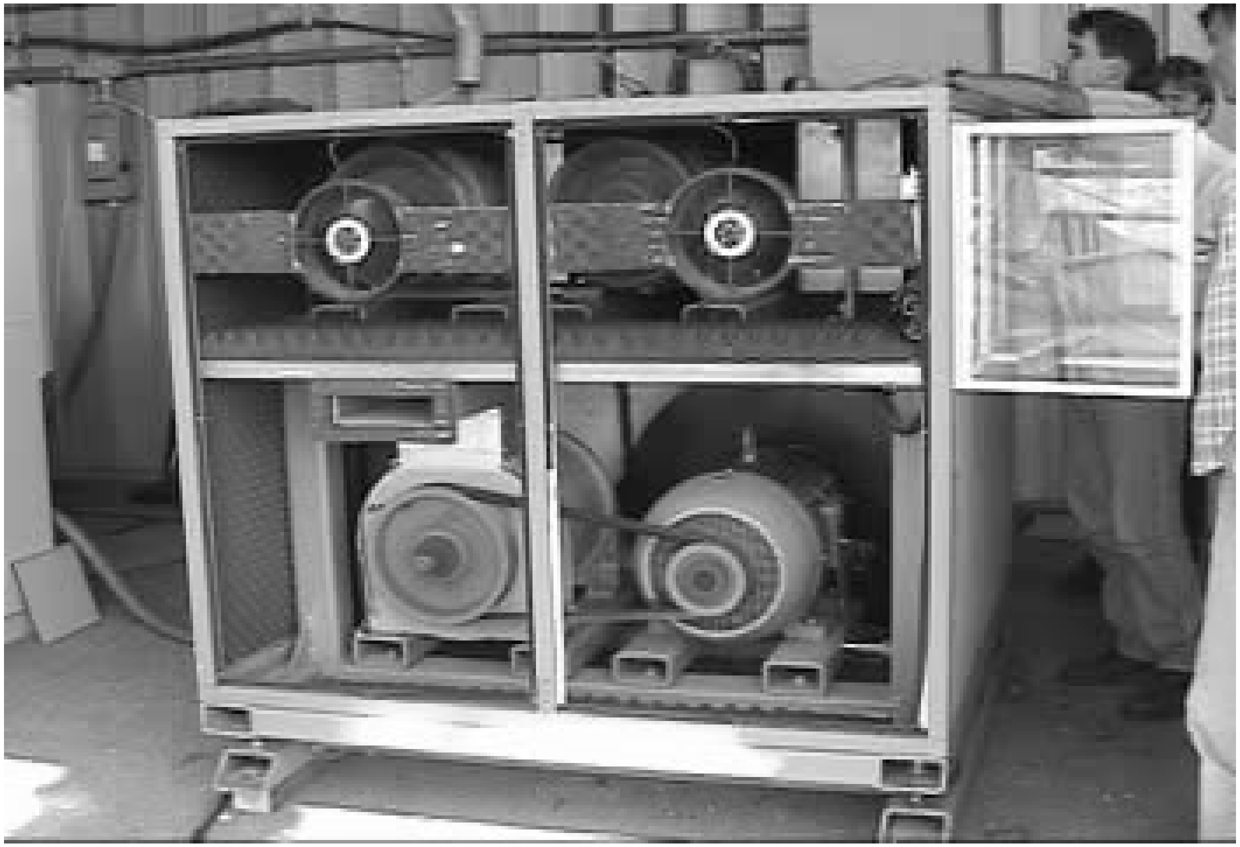
Phase 1 Task 3
Test System 1



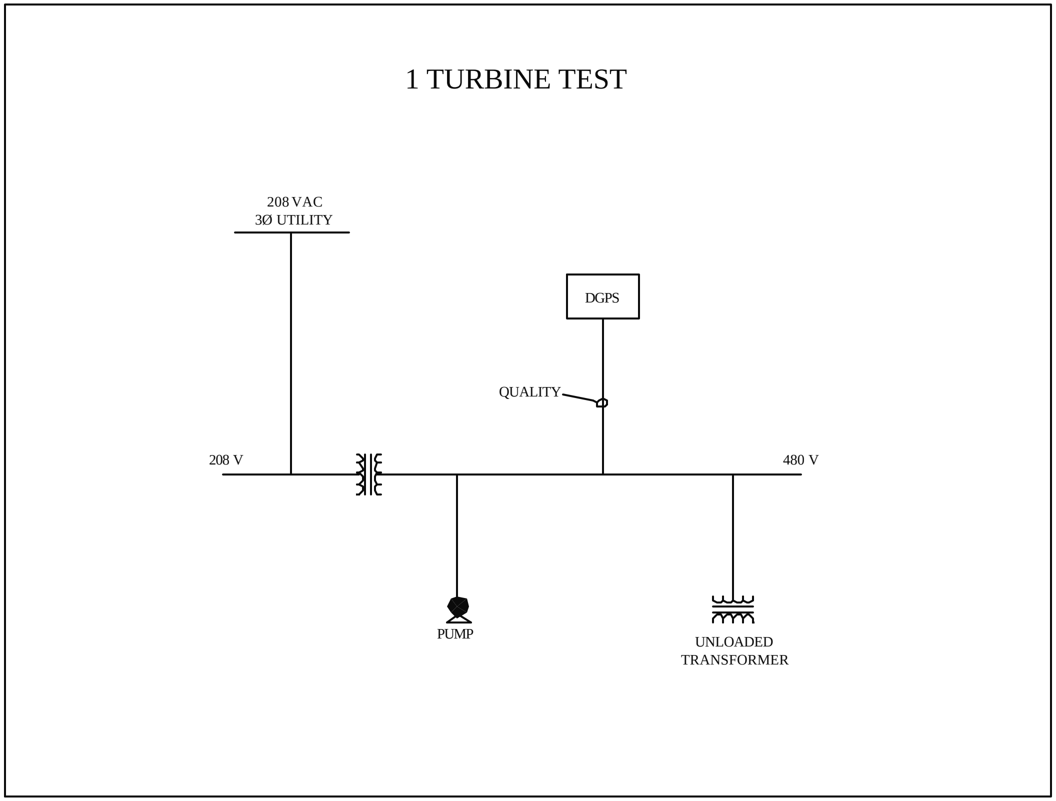
Phase 1 Task 3
Test System 2

- **Test system constructed to consider:**
  - **Micro turbine performance**
  - **Response of micro turbines to each other and with energy storage devices (fly wheel)**
  - **Power Quality**
  - **Transient response**

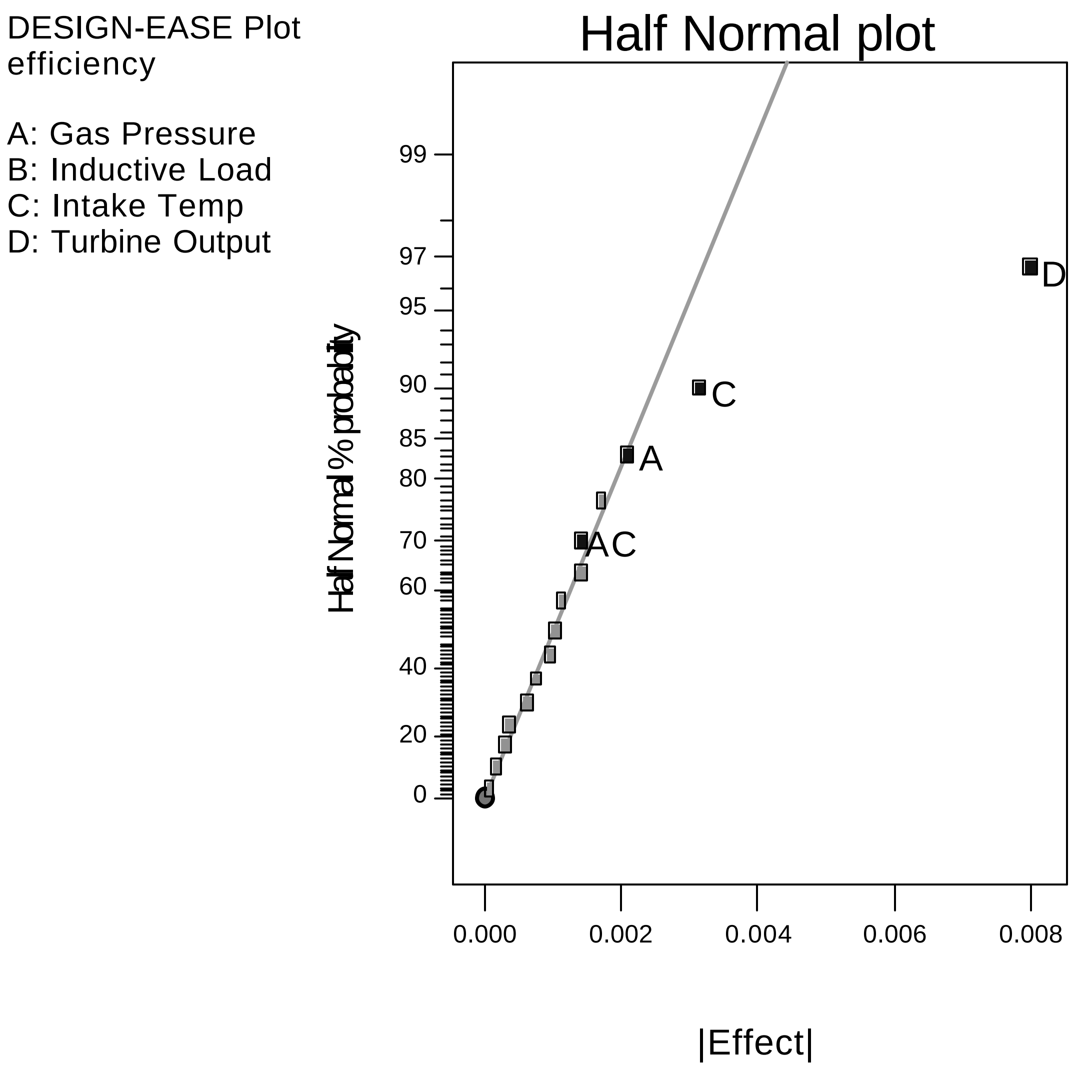
Phase 1 Task 3
Test System 2



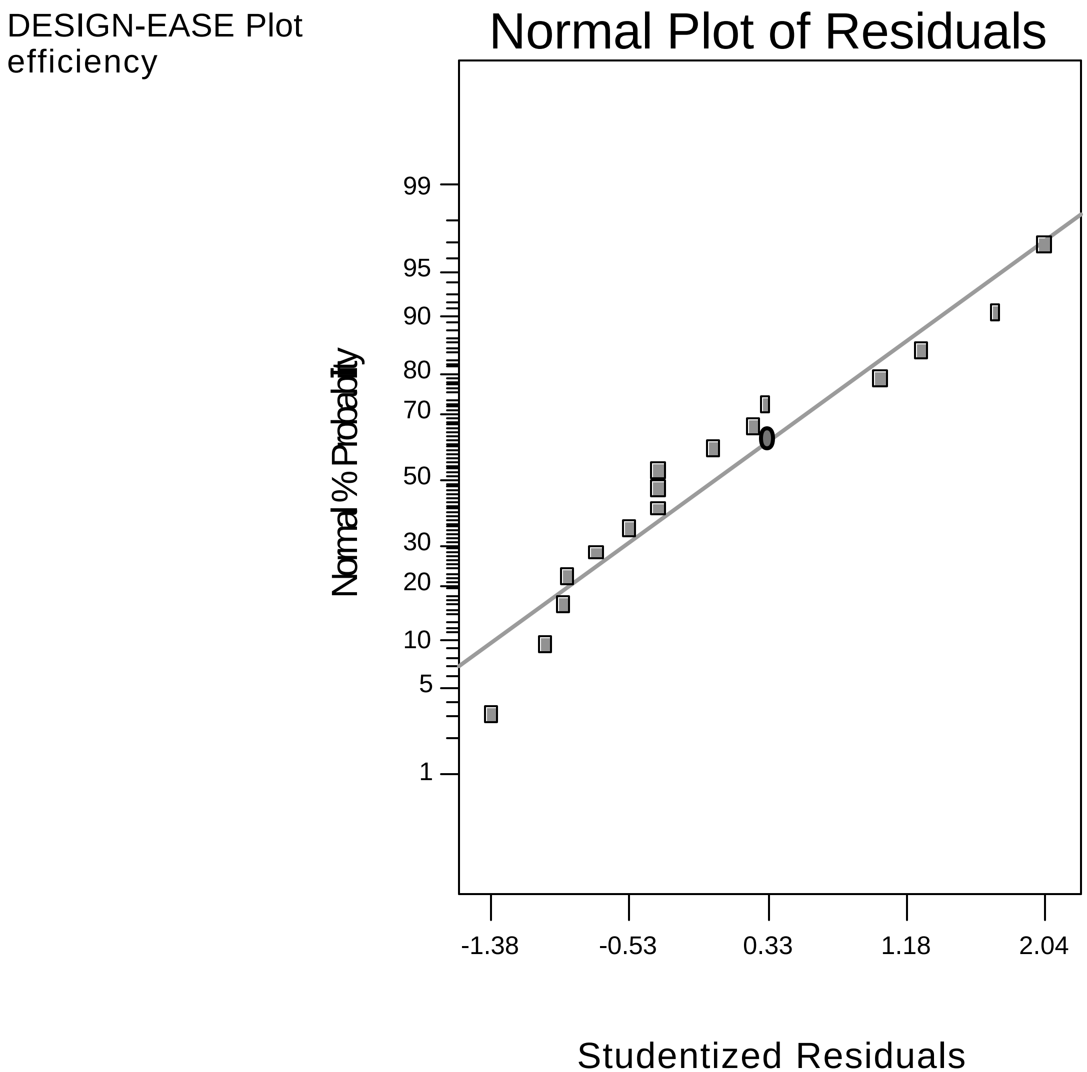
Phase 1 Task 3
Test System 2
Test 1



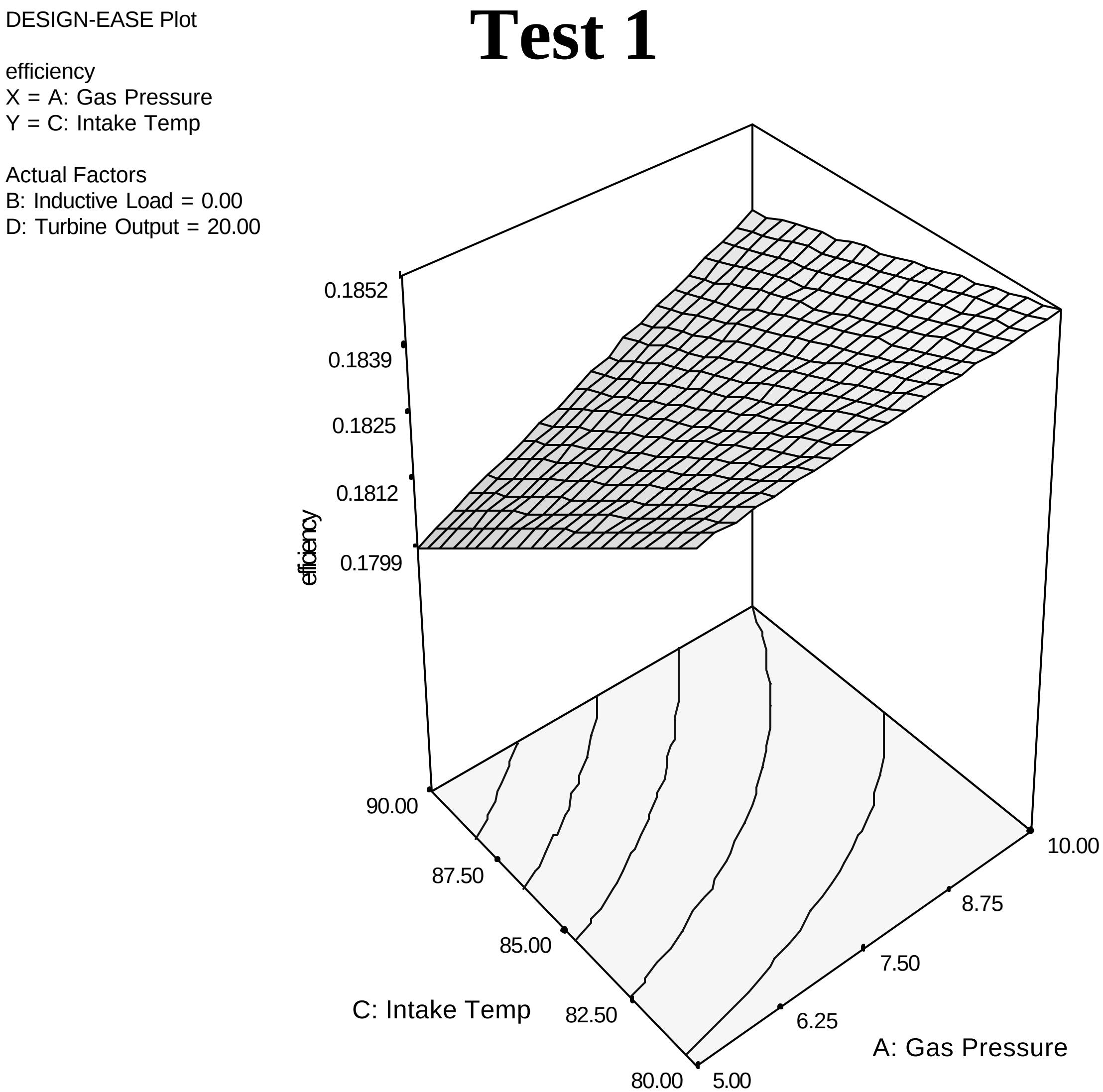
Phase 1 Task 3
Test System 2
Test 1



Phase 1 Task 3
Test System 2
Test 1



Phase 1 Task 3
Test System 2
Test 1

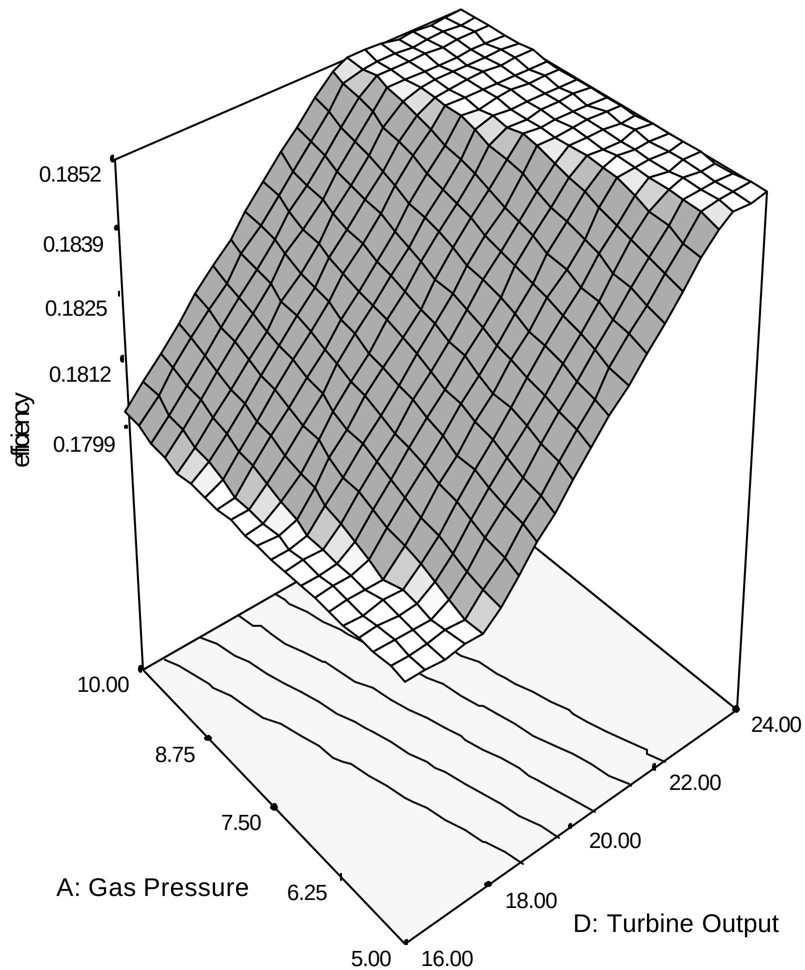


Phase 1 Task 3
Test System 2
Test 1

DESIGN-EASE Plot

efficiency
X = D: Turbine Output
Y = A: Gas Pressure

Actual Factors
B: Inductive Load = 0.00
C: Intake Temp = 85.00

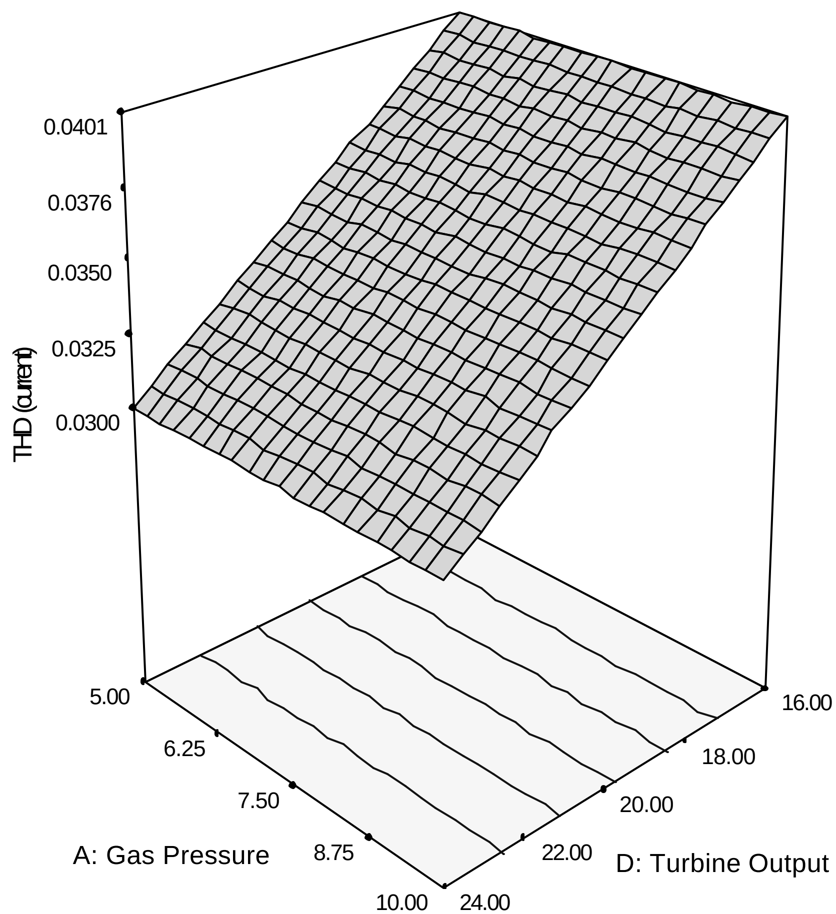


Phase 1 Task 3
Test System 2
Test 1

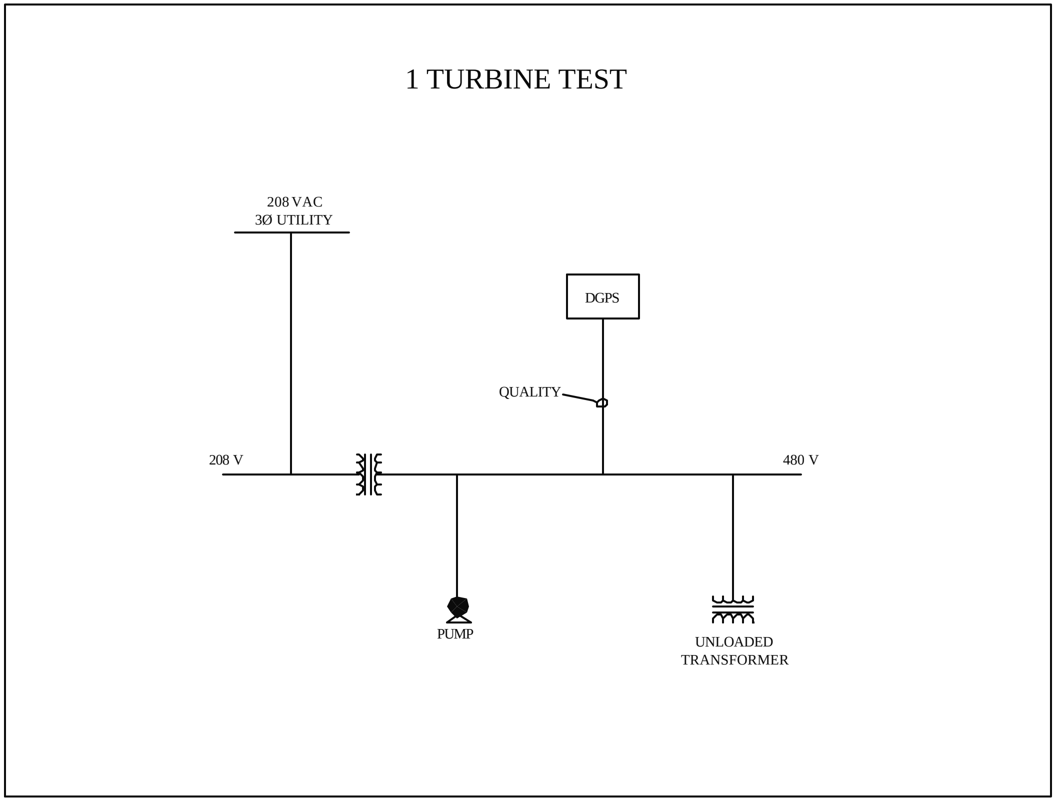
DESIGN-EASE Plot

THD (current)
X = D: Turbine Output
Y = A: Gas Pressure

Actual Factors
B: Inductive Load = 0.00
C: Intake Temp = 85.00



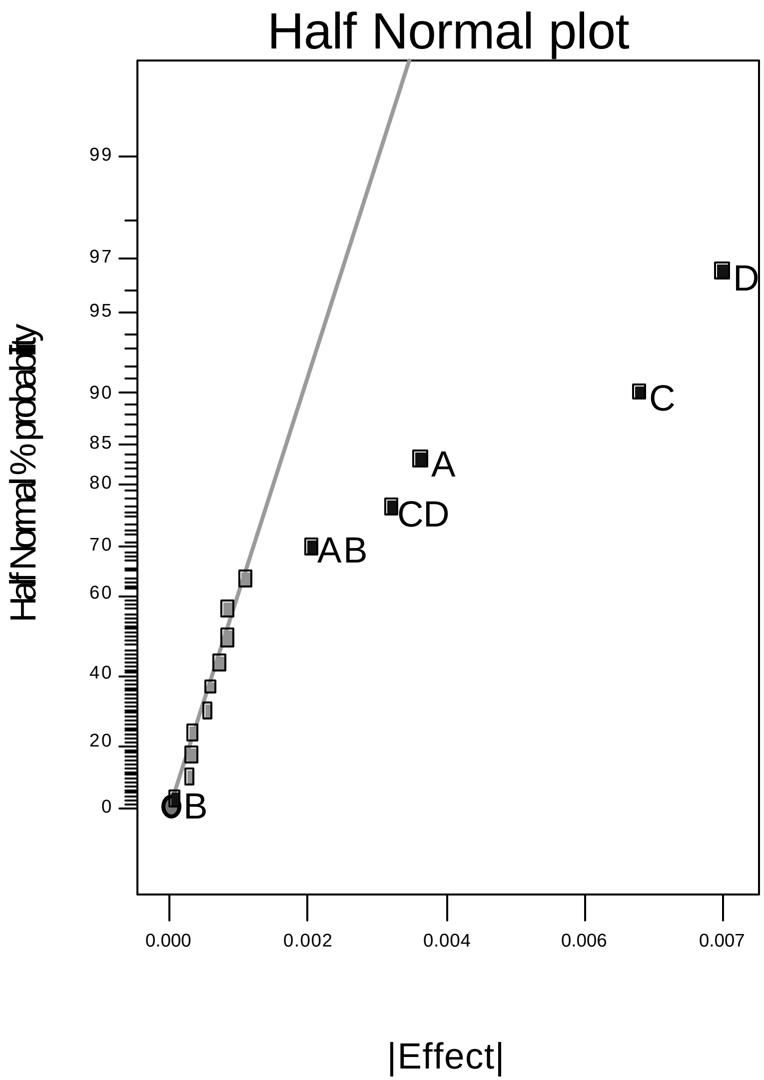
Phase 1 Task 3
Test System 2
Test 2



Phase 1 Task 3
Test System 2
Test 2

DESIGN-EASE Plot
efficiency

A: Gas Pressure
B: Inductive Load
C: Intake Temp
D: Turbine Ouput

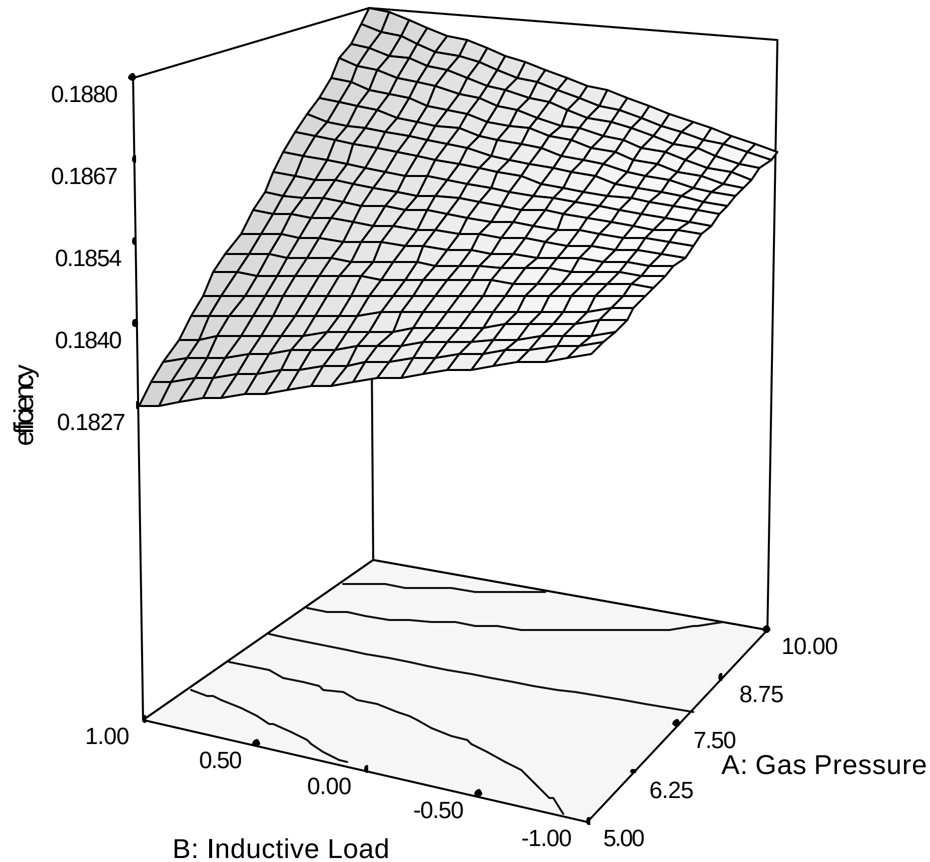


Phase 1 Task 3
Test System 2
Test 2

DESIGN-EASE Plot

efficiency
X = A: Gas Pressure
Y = B: Inductive Load

Actual Factors
C: Intake Temp = 85.00
D: Turbine Ouput = 20.00

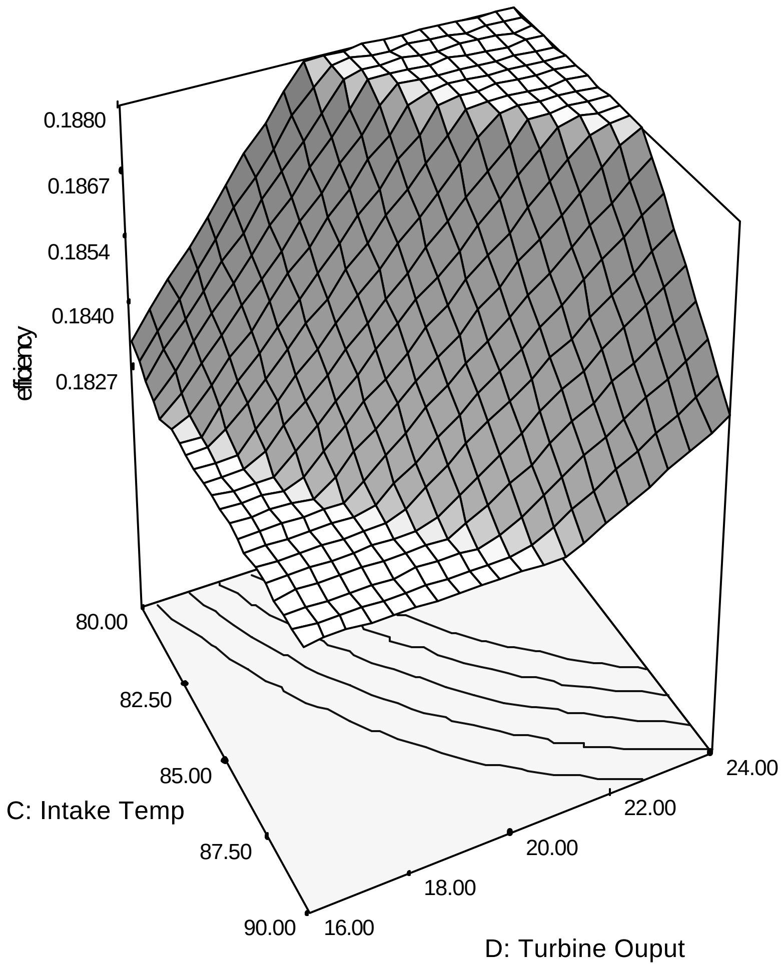


Phase 1 Task 3
Test System 2
Test 2

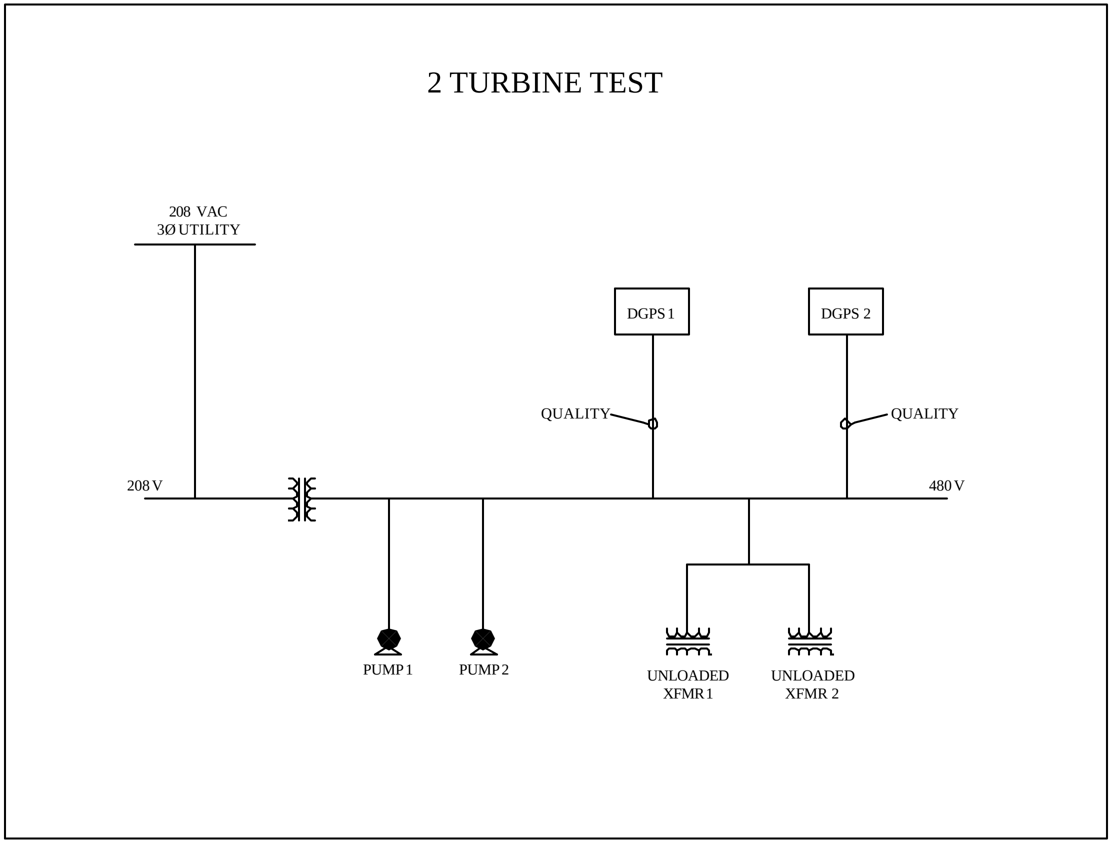
DESIGN-EASE Plot

efficiency
X = C: Intake Temp
Y = D: Turbine Ouput

Actual Factors
A: Gas Pressure = 7.50
B: Inductive Load = 0.00



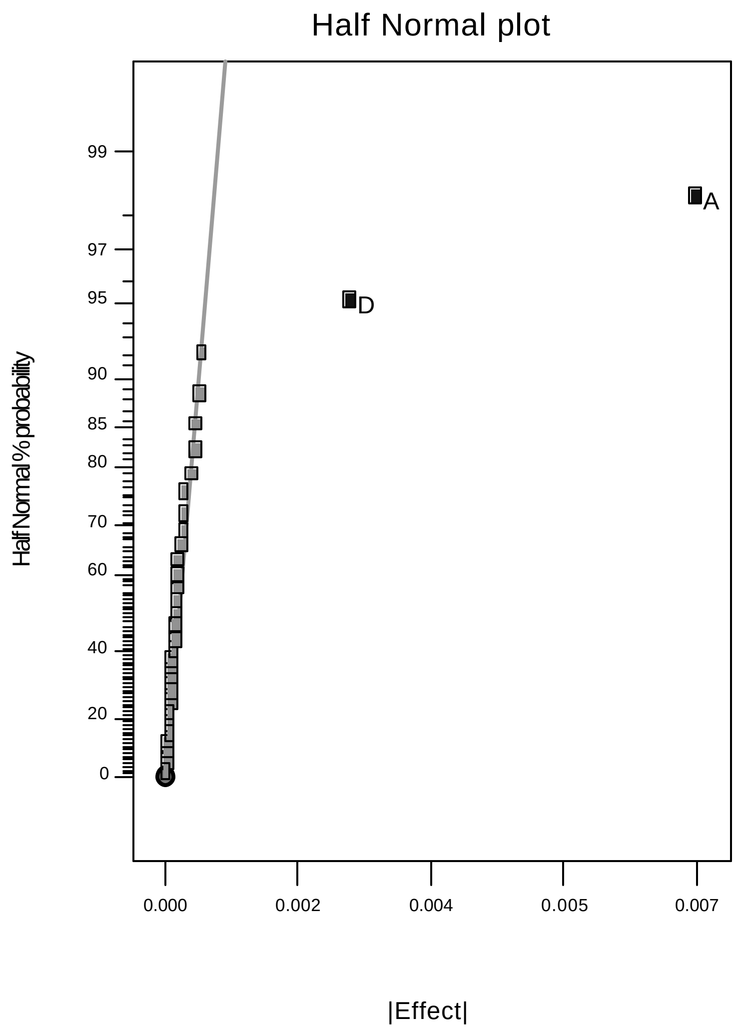
Phase 1 Task 3
Test System 2
Test 3



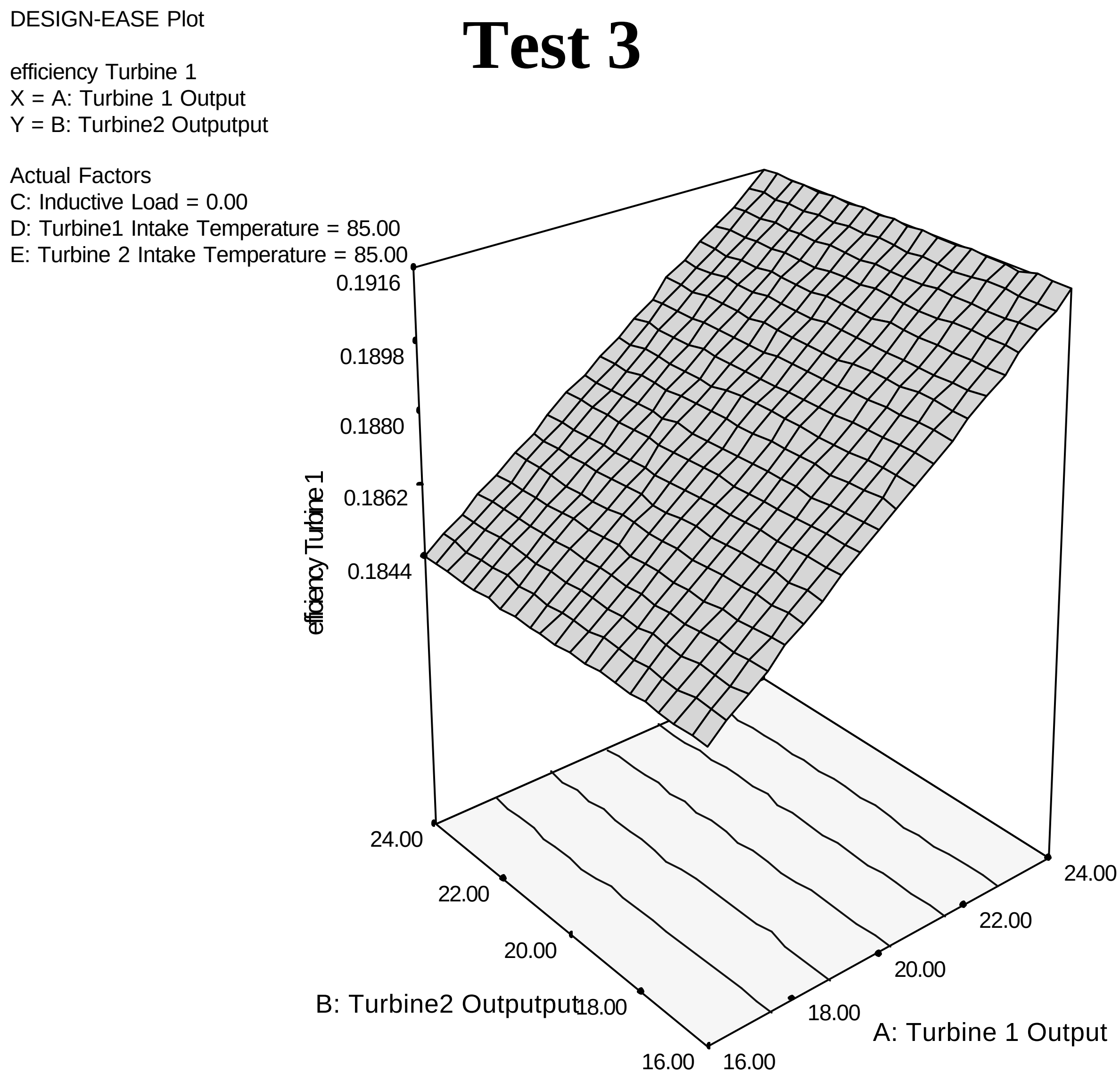
Phase 1 Task 3
Test System 2
Test 3

DESIGN-EASE Plot
efficiency Turbine 1

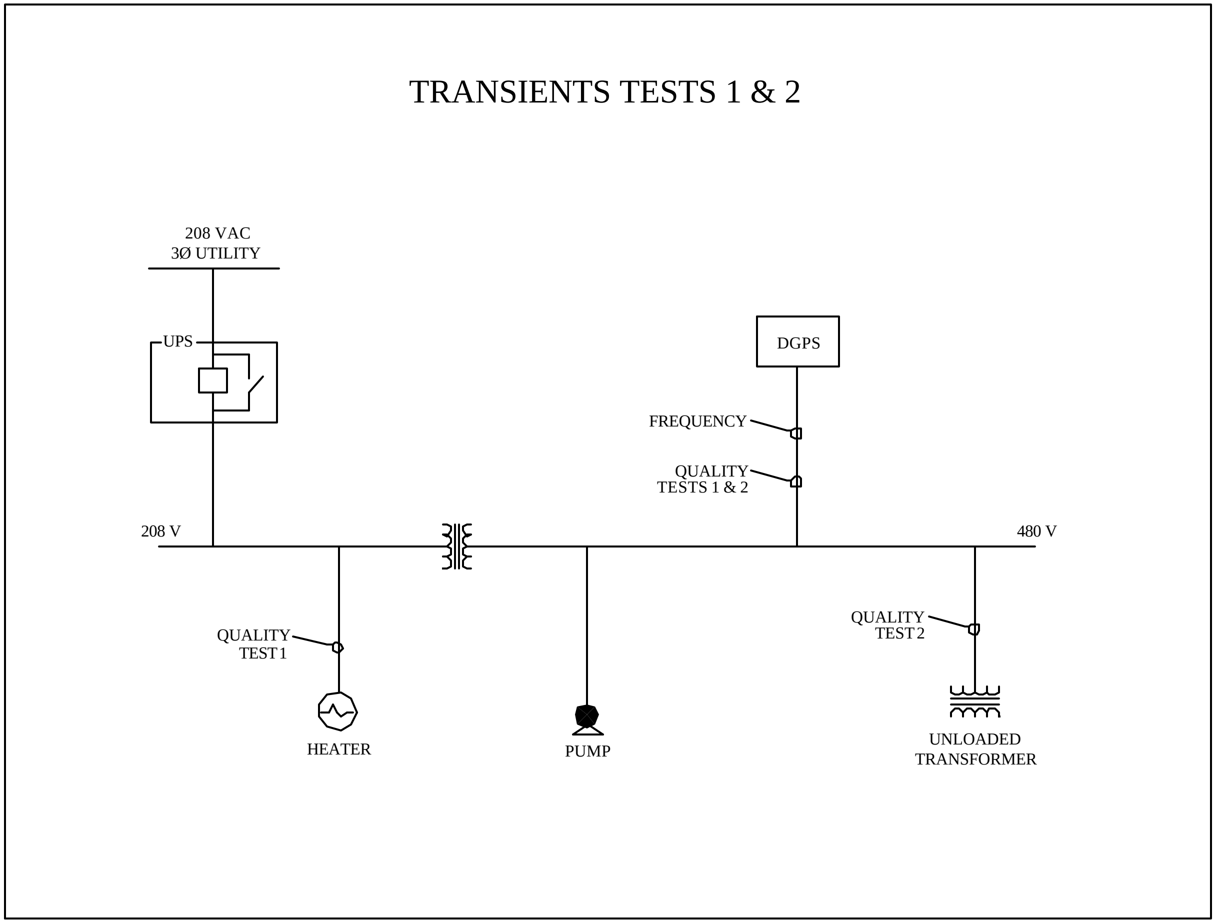
A: Turbine 1 Output
B: Turbine2 Outputput
C: Inductive Load
D: Turbine1 Intake Temperature
E: Turbine 2 Intake Temperature



Phase 1 Task 3
Test System 2
Test 3

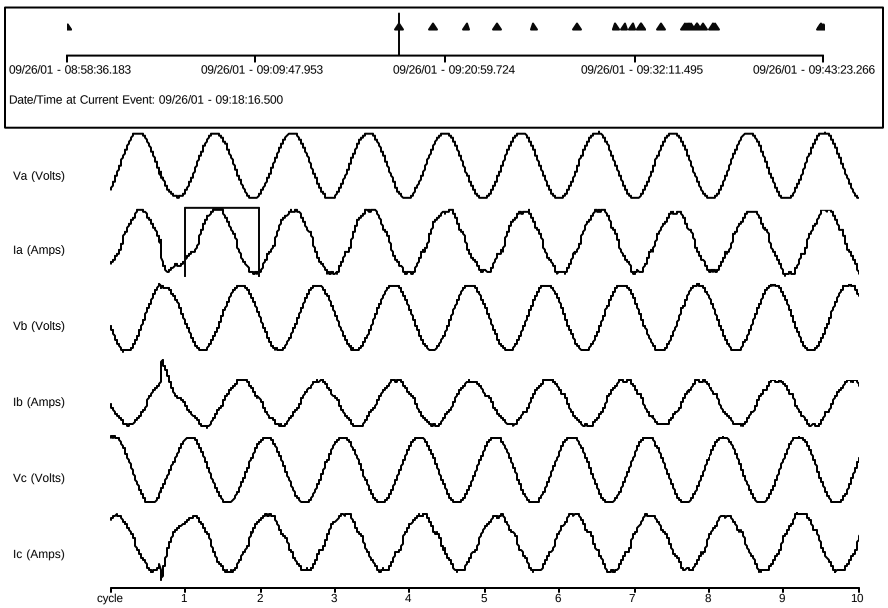


Phase 1 Task 3
Test System 2
Test 4



Phase 1 Task 3
Test System 2
Test 4

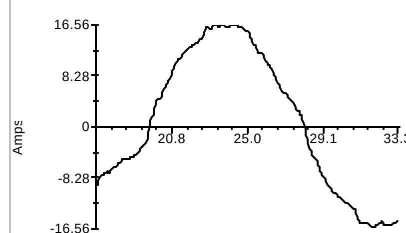
Current and Harmonic Distortion for Resistive Transient



Event: 4 Of 40
Duration: 21 Cycles

Event Trigger Input 5 Vc Volts (LOWER)
Event Trigger Cycle 1

Time:	09/26/01 09:18:16.500
Input:	Ia Amps
Cycle:	2



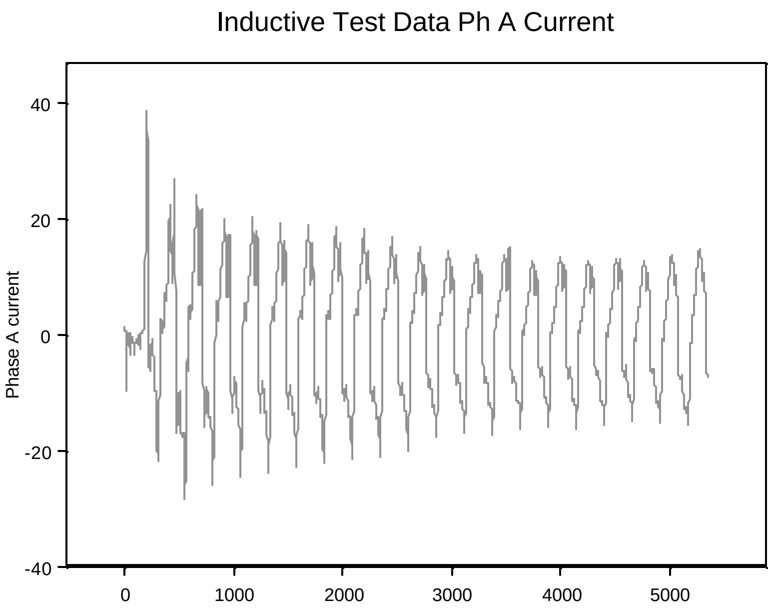
Cycle Waveform

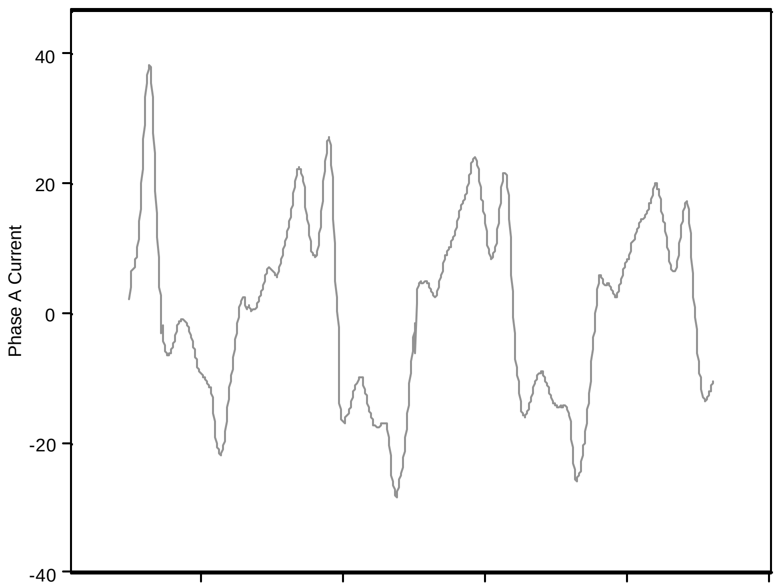
Total Harmonic Distortion	11.48 %
Odd Contribution	9.09 %
Even Contribution	7.01 %
RMS Of Fundamental	11.27 A
RMS Of Fund + Harm	11.36 A
K Factor	2.19

Harm	% Of Fund	Amps	Angle	Harm	% Of Fund	Amps	Angle
Fund	100.00	11.3	0°	2	3.95	0.4	176°
3	4.06	0.5	243°	4	3.89	0.4	269°
5	6.78	0.8	300°	6	2.79	0.3	14°
7	1.78	0.2	334°	8	1.41	0.2	93°
9	1.24	0.1	185°	10	0.56	0.1	264°
11	3.07	0.3	310°	12	1.48	0.2	17°
13	0.86	0.1	21°	14	0.76	0.1	131°
15	0.91	0.1	200°	16	1.07	0.1	272°
17	1.32	0.1	281°	18	1.05	0.1	356°
19	0.25	0.0	143°	20	0.32	0.0	166°
21	0.44	0.0	169°	22	0.61	0.1	297°
23	0.81	0.1	255°	24	0.82	0.1	346°
25	0.53	0.1	72°	26	0.45	0.1	142°
27	0.45	0.1	190°	28	0.64	0.1	249°
29	0.30	0.0	285°	30	0.15	0.0	327°
31	0.47	0.1	71°	32	0.27	0.0	126°
33	0.28	0.0	232°	34	0.50	0.1	279°
35	0.28	0.0	330°	36	0.43	0.0	28°
37	0.38	0.0	44°	38	0.04	0.0	218°
39	0.40	0.0	194°	40	0.35	0.0	301°
41	0.27	0.0	315°	42	0.46	0.1	350°
43	0.10	0.0	320°	44	0.26	0.0	160°
45	0.19	0.0	178°	46	0.52	0.1	257°
47	0.28	0.0	324°	48	0.16	0.0	47°
49	0.09	0.0	84°	50	0.29	0.0	155°
51	0.22	0.0	205°	52	0.21	0.0	291°
53	0.17	0.0	356°	54	0.20	0.0	45°
55	0.18	0.0	118°	56	0.27	0.0	164°
57	0.17	0.0	220°	58	0.09	0.0	303°
59	0.18	0.0	328°	60	0.18	0.0	51°
61	0.22	0.0	123°	62	0.12	0.0	162°
63	0.18	0.0	239°				

Phase 1 Task 3
Test System 2
Test 4

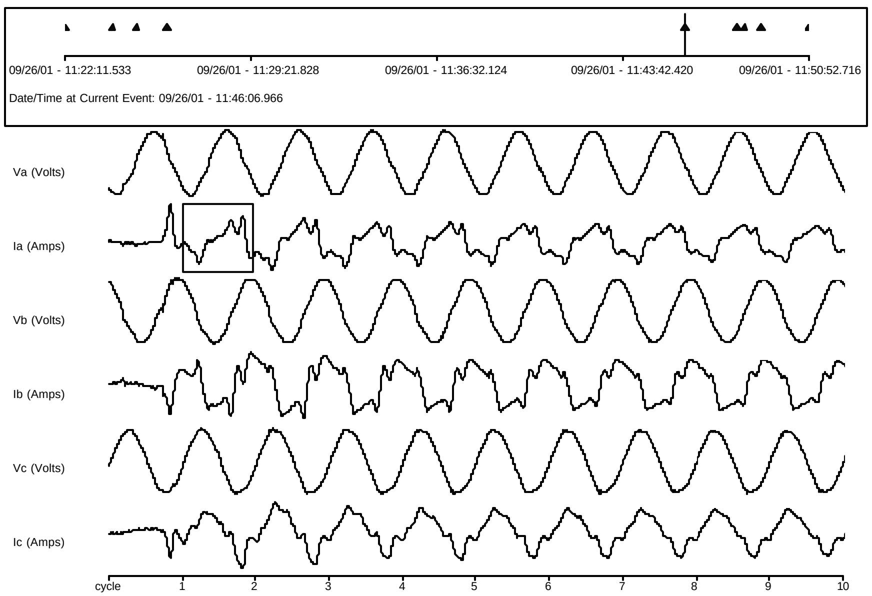
Inductive Transient





Phase 1 Task 3
Test System 2
Test 4

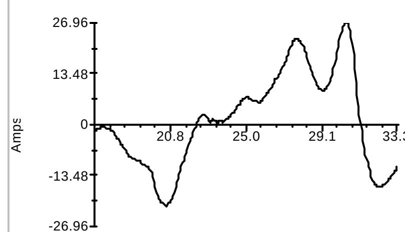
Current and Harmonic Distortion for Inductive Transient



Event: 9 Of 17
Duration: 21 Cycles

Event Trigger Input 6 Ic Amps (THD)
Event Trigger Cycle 1

Time:	09/26/01 11:46:06.967
Input:	Ia Amps
Cycle:	2



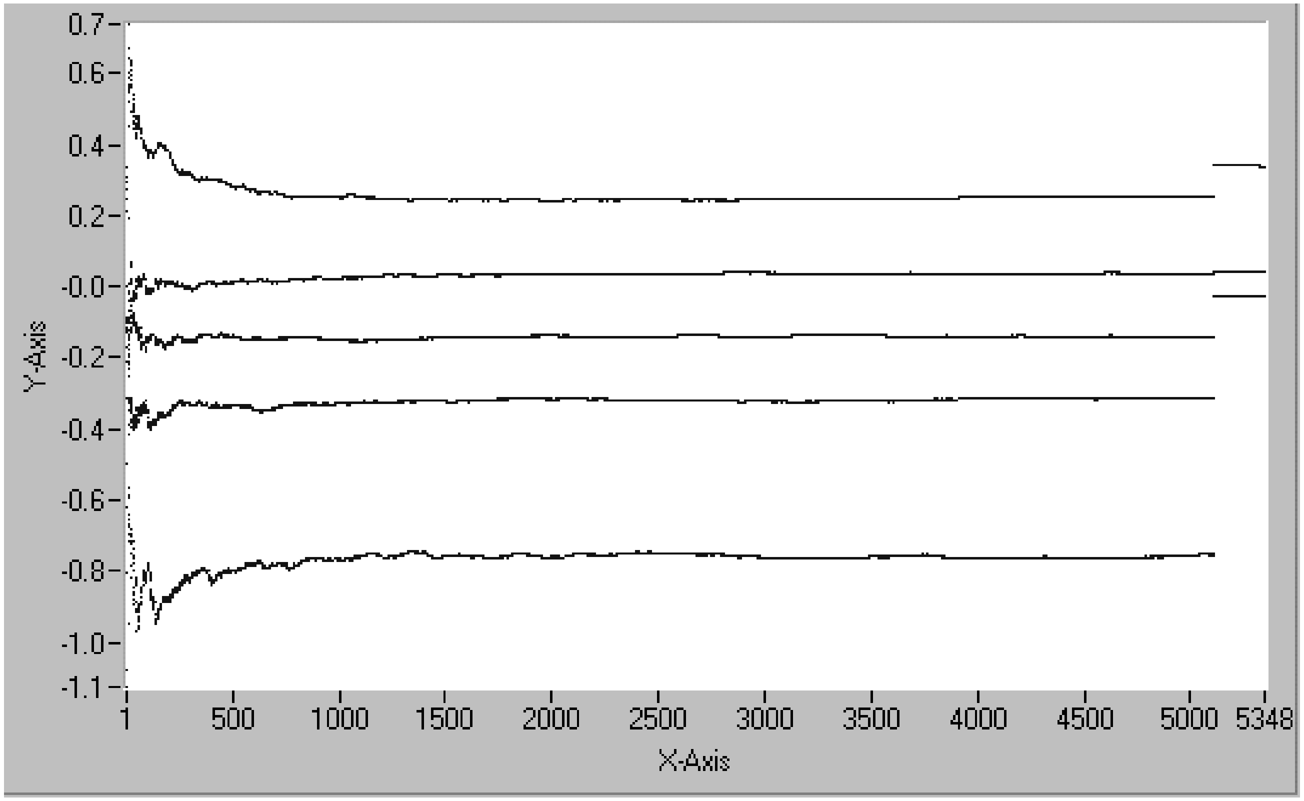
Cycle Waveform

Total Harmonic Distortion	68.80 %
Odd Contribution	44.14 %
Even Contribution	52.77 %
RMS Of Fundamental	10.44 A
RMS Of Fund + Harm	12.70 A
K Factor	9.73

Harm	% Of Fund	Amps	Angle	Harm	% Of Fund	Amps	Angle
Fund	100.00	10.4	0°	2	14.02	1.5	242°
3	36.29	3.8	88°	4	36.83	3.8	205°
5	22.52	2.4	51°	6	33.43	3.5	265°
7	5.21	0.5	118°	8	7.94	0.8	14°
9	7.40	0.8	207°	10	2.56	0.3	38°
11	5.01	0.5	233°	12	5.15	0.5	54°
13	0.48	0.1	19°	14	0.05	0.0	338°
15	1.25	0.1	59°	16	1.65	0.2	219°
17	2.14	0.2	47°	18	2.28	0.2	190°
19	1.12	0.1	326°	20	0.93	0.1	182°
21	0.51	0.1	308°	22	1.00	0.1	86°
23	1.63	0.2	215°	24	1.02	0.1	322°
25	0.88	0.1	179°	26	0.78	0.1	334°
27	0.57	0.1	90°	28	0.70	0.1	257°
29	0.81	0.1	22°	30	0.61	0.1	153°
31	0.98	0.1	344°	32	0.83	0.1	164°
33	0.63	0.1	311°	34	0.59	0.1	60°
35	0.15	0.0	160°	36	0.63	0.1	21°
37	0.74	0.1	131°	38	0.86	0.1	307°
39	1.04	0.1	111°	40	0.60	0.1	279°
41	0.67	0.1	85°	42	0.57	0.1	195°
43	0.23	0.0	356°	44	0.39	0.0	147°
45	0.60	0.1	263°	46	0.58	0.1	65°
47	0.49	0.1	221°	48	0.42	0.0	46°
49	0.58	0.1	183°	50	0.34	0.0	312°
51	0.32	0.0	107°	52	0.42	0.0	251°
53	0.47	0.0	56°	54	0.43	0.0	210°
55	0.42	0.0	355°	56	0.37	0.0	139°
57	0.38	0.0	281°	58	0.42	0.0	76°
59	0.37	0.0	238°	60	0.40	0.0	37°
61	0.41	0.0	177°	62	0.35	0.0	328°
63	0.37	0.0	120°				

Phase 1 Task 3
Test System 2
Test 4

Lyapunov Spectrum Phase A Current
Inductive Transient



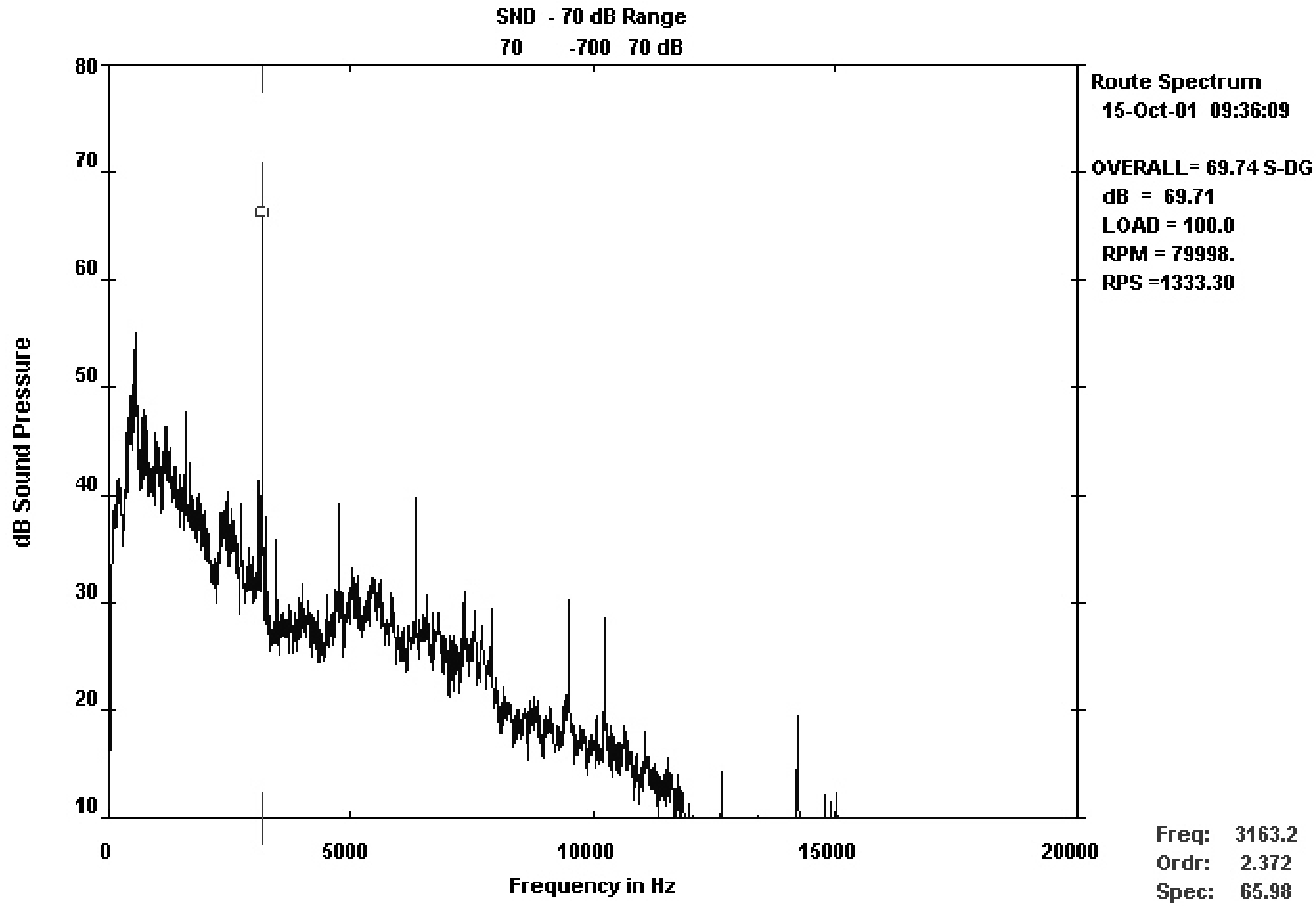
Phase 1 Task 3
Test System 2
Test 5

Emissions Test Results

Additional Test Results

- ***Please see final report for complete details.***
  - Too voluminous to list here

Phase 1 Task 3
Test System 2
Test 6
Acoustic Measurements

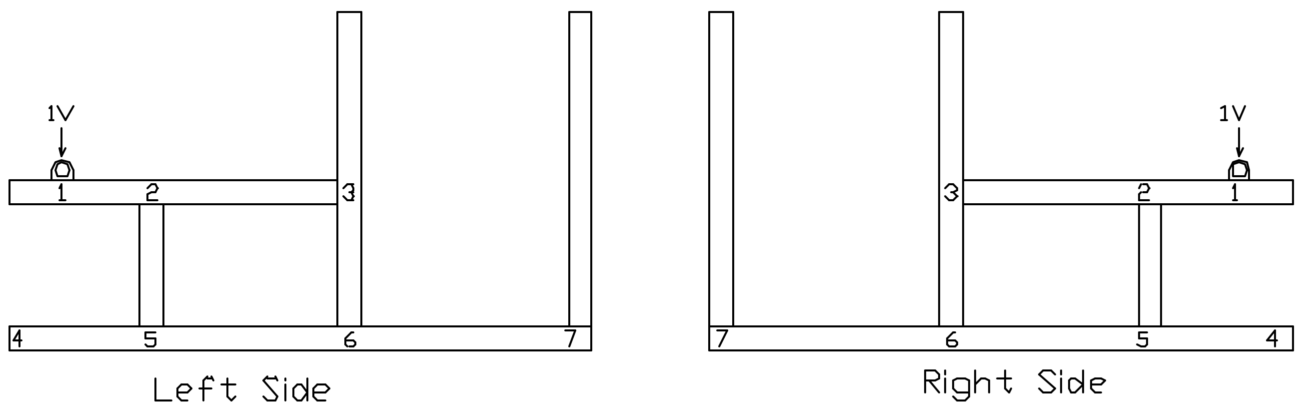


Phase 1 Task 3
Test System 2
Test 6
Acoustic Measurements

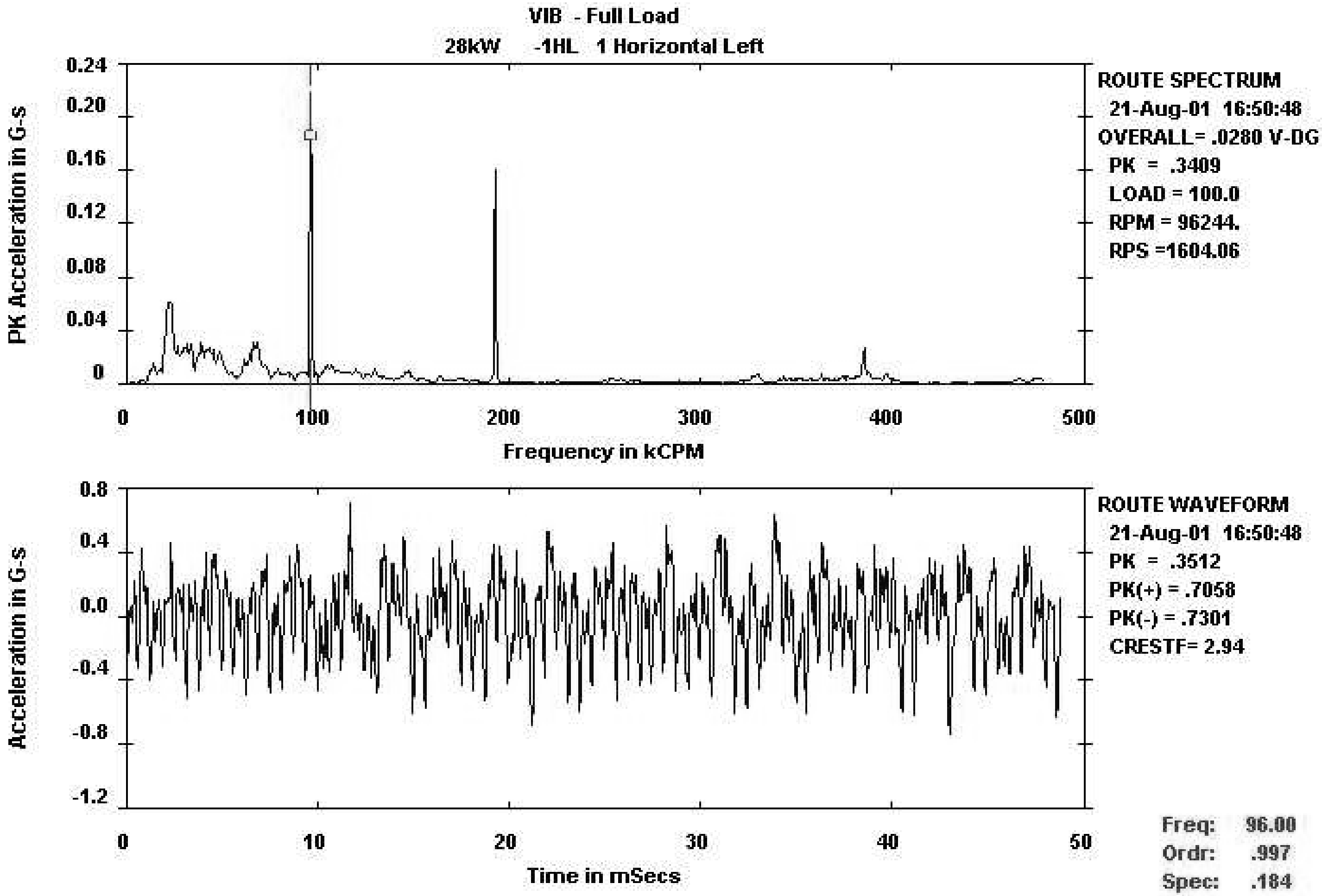
Additional Test Results

- ***Please see final report for complete details.***
  - Too voluminous to list here

Phase 1 Task 3
Test System 2
Test 7
Vibration Measurements
Position on Frame



Phase 1 Task 3
Test System 2
Test 7
Vibration Measurements



Phase 1 Task 3
Test System 2
Test 7
Vibration Measurements

Additional Test Results

- ***Please see final report for complete details.***
  - Too voluminous to list here

Phase II - (Second Year)
Total Building Integration and System Optimization

- **In this phase, the "system" will be the entire building (a comprehensive approach)**
- **Total building interface will be realized incorporating sustainable architecture, design, artificial intelligence and advanced controls, and interconnection with the larger grid.**
- **Research will include determining how a comprehensive distributed power building system performs, interfaces, and can be optimized with the electric grid.**

Phase II Tasks

- Task 4: System Design
- Task 5: Interconnection
- Task 6: System Performance

Review of Second Project

Enhancing the Operation of Highly Varying Industrial Loads to Increase Electric Reliability, Quality, and Economics

Department of Energy

NiSource Energy Technologies

Purdue University

Colorado School of Mines

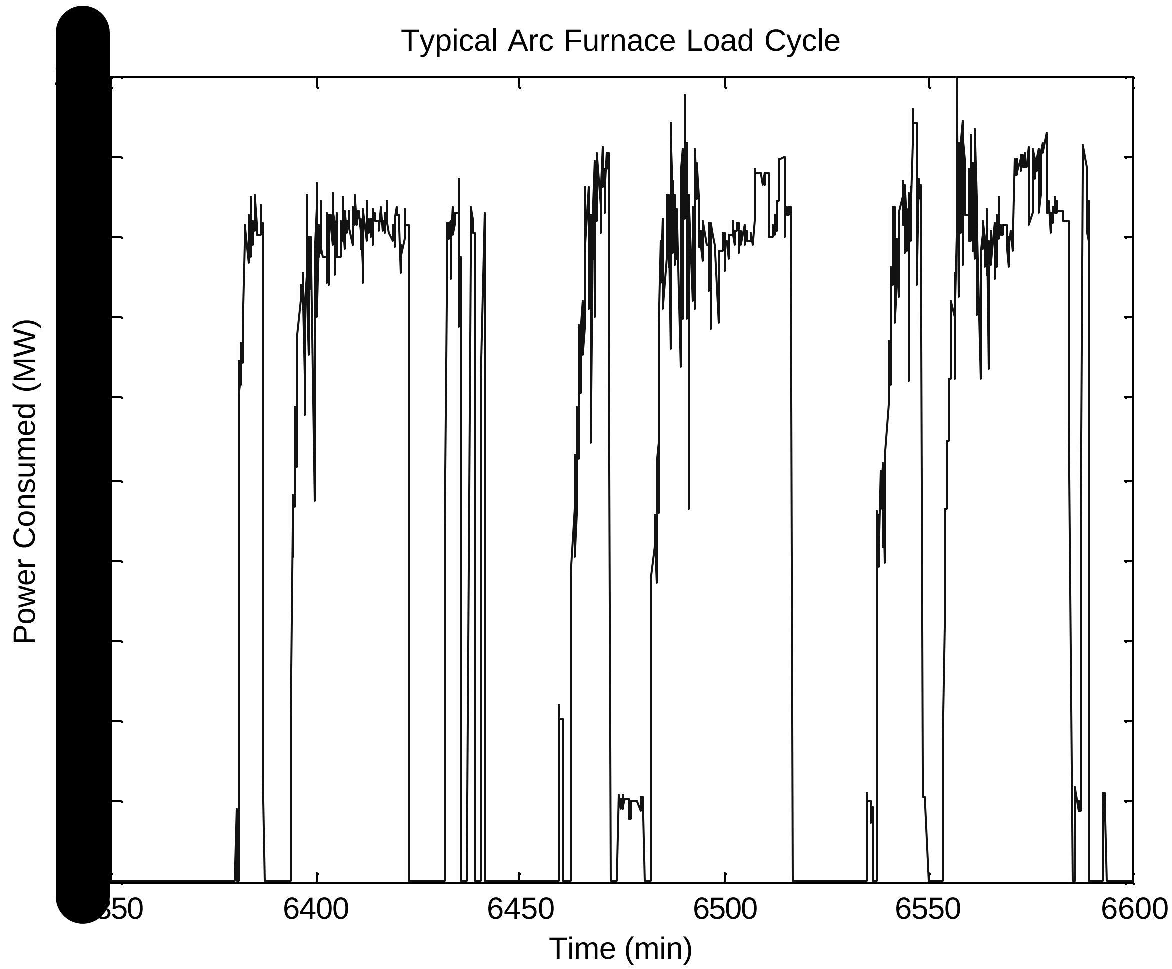
Subcontract # 45 000 13 009

Oak Ridge National Laboratory, UT- Battelle

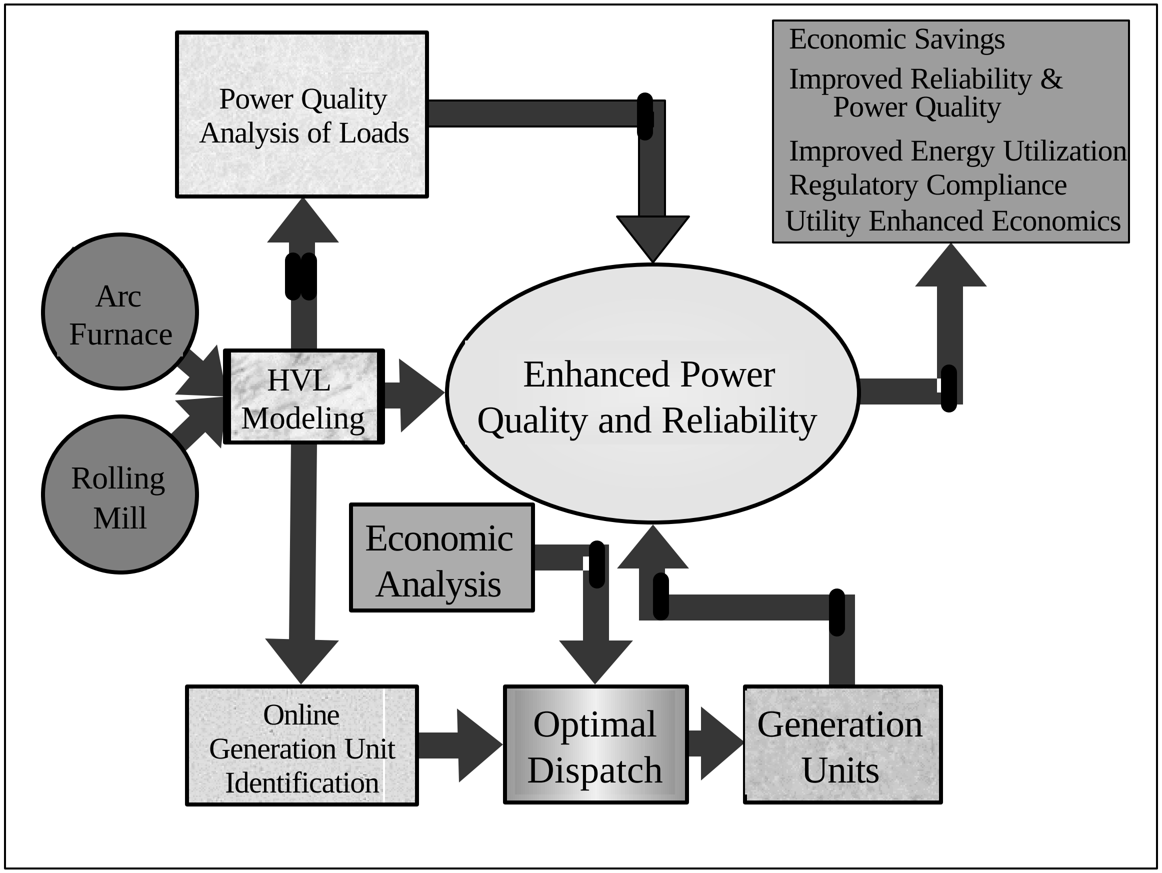
Goals and Methodologies

- ***Goal***
  - Develop a way to increase electric reliability and quality by reducing the electric fluctuations caused by large industrial loads without reducing (and hopefully increasing) productivity.
- ***Method***
  - Develop ways to coordinate startup of large loads so that they tend to cancel out the electric transients from each other.

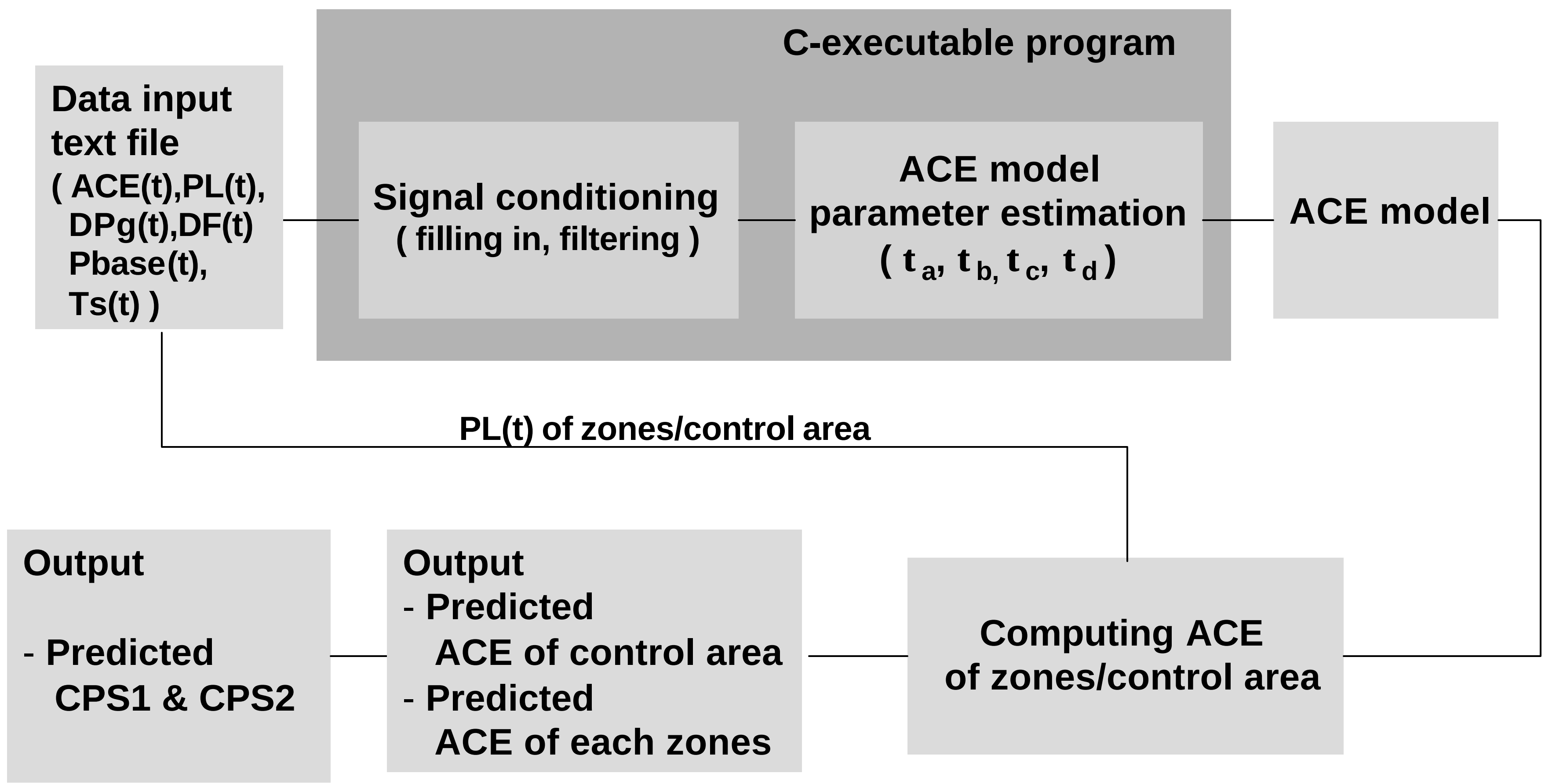
Large Load Swings



Outline of Final Deliverable

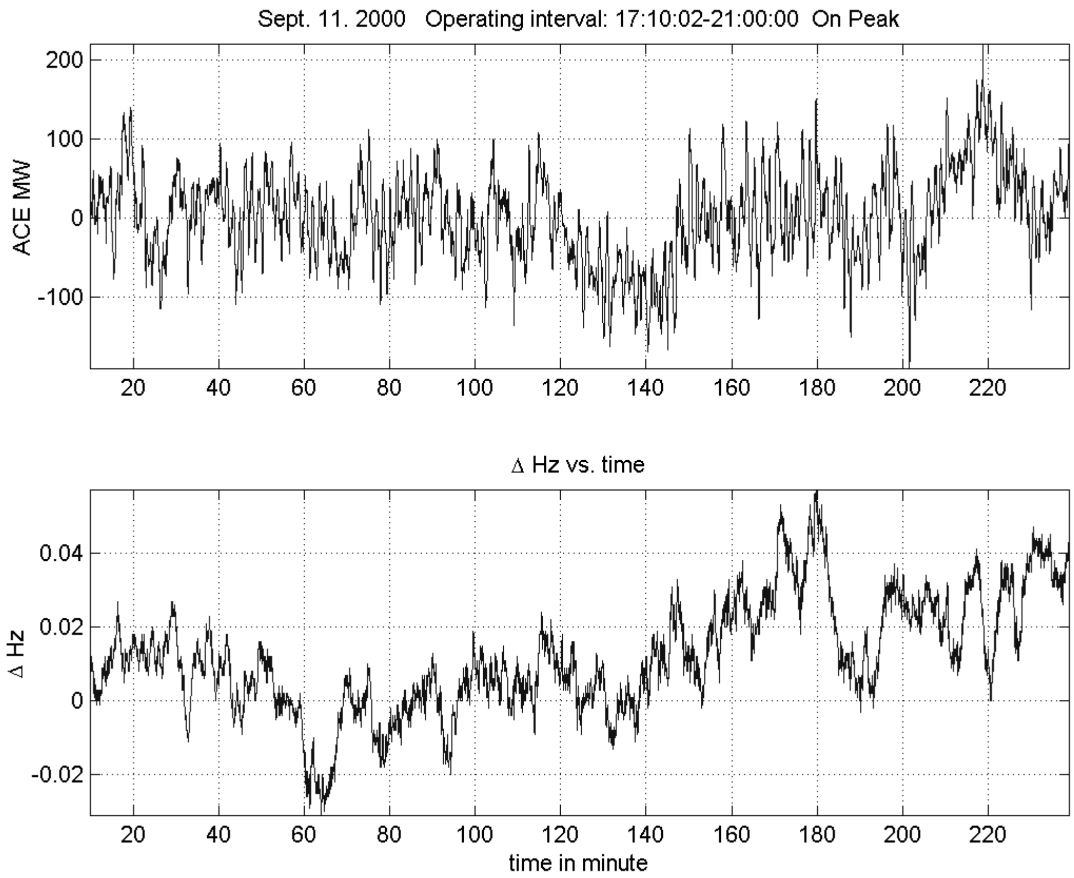


Sub Allocation of Control



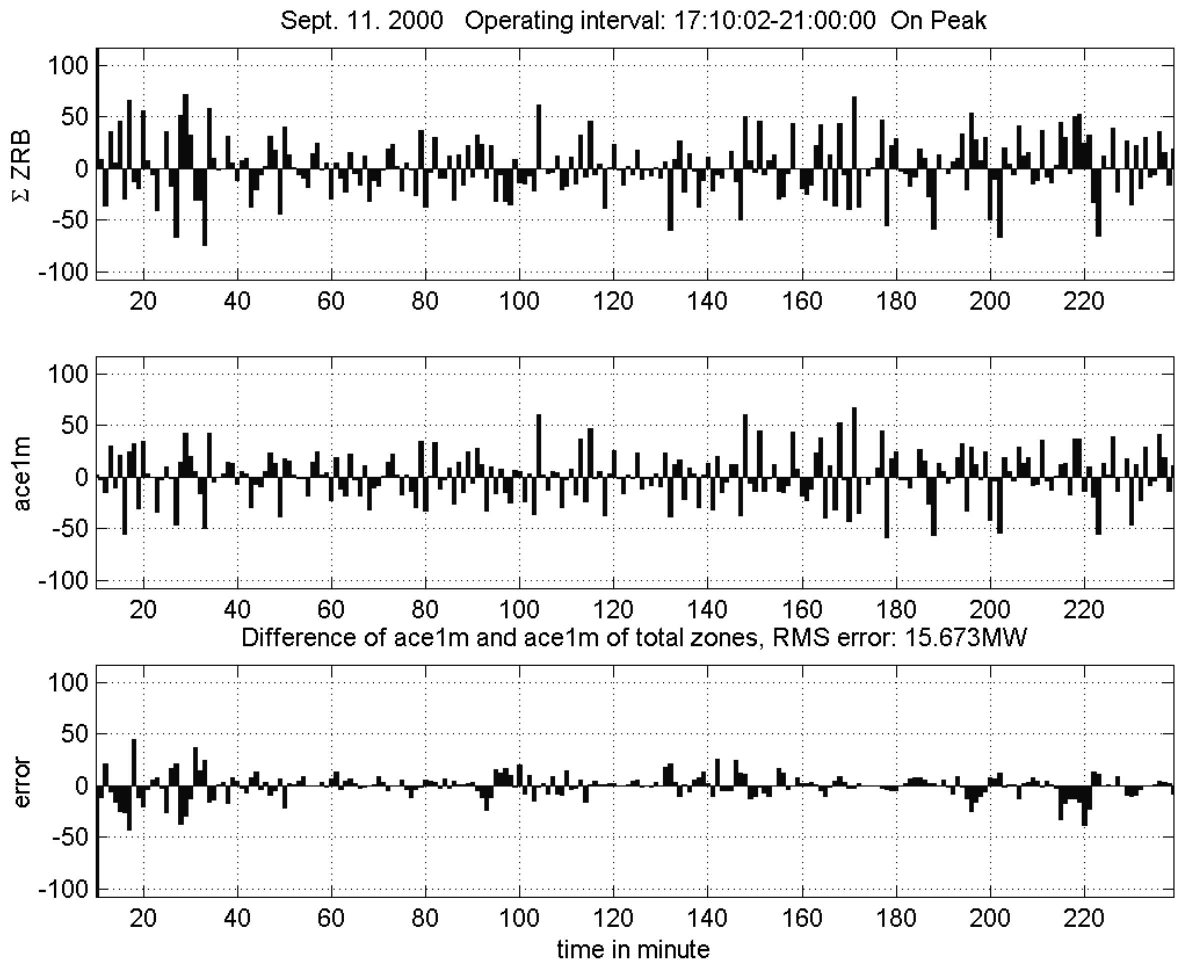
Sub Allocation of Control

Ace and DF



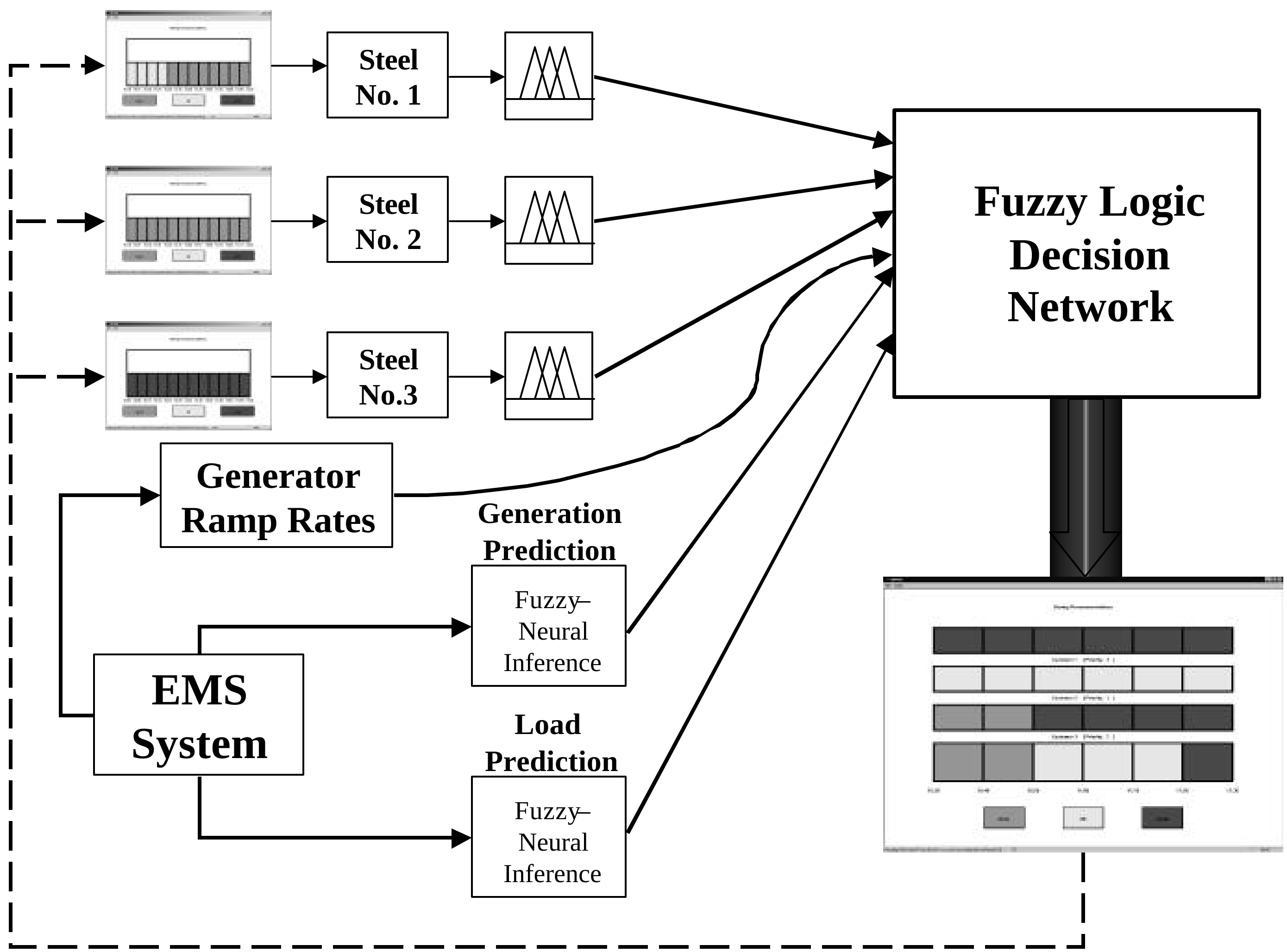
Sub Allocation of Control

Predicted and Experimental ACE Comparison



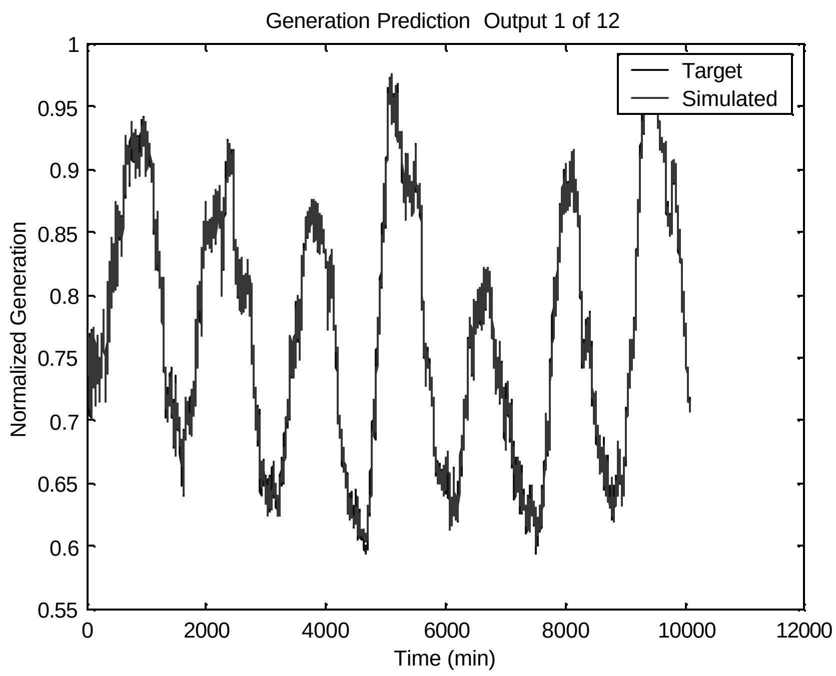
Prediction of Highly Varying Loads

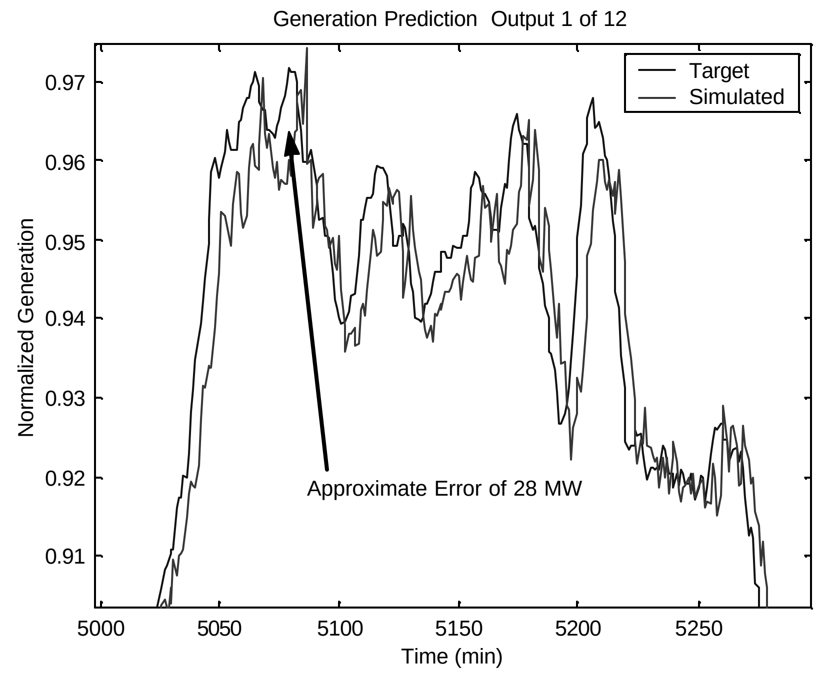
HVL Coordination System



Prediction of Highly Varying Loads

Comparison of Results





Economic Considerations

In an ideal system, generating units would be able to follow all load fluctuations perfectly, with generation matching load exactly. However, in the real world, the ideal system is unachievable due to the limitations of control systems, the slow response of generating units due to inertia, and the unpredictable nature of load variations.

The costs associated with providing regulation have been categorized here into 9 types of costs:

- **Wear & Tear Costs (including Fixed, and Variable Operation & Maintenance Costs)**
  - Cycling of generators causes increased wear and tear.
- **Cost of Departure from Optimum Heat Rate**
  - Individual units on AGC are not usually operated at the optimum heat rate, resulting in higher fuel costs.
- **Cost of Departure from Optimum Dispatch Order (Ramp Limits)**
  - Having units available for AGC results in a departure from the optimum dispatch order, resulting in higher fuel costs.
- **Cost of Departure from Optimum Unit Commitment**
  - This is the cost of committing extra units in anticipation of having to serve highly varying loads.
- **Decreased Revenue/Increased Cost due to Transmission (Opportunity Cost)**
  - Highly varying loads cause short-term imports/exports from/to neighboring control areas.
- **Environmental Costs/Benefits**
  - The change in dispatch resulting from AGC as compared to the optimal dispatch order causes the environmental impacts (e.g., air emissions, water discharge) to change.
- **Cost of AGC System**
- **Cost of Anticipating Highly Varying Load (Extra Spinning Reserve to allow AGC to function)**
  - Units on AGC may have a more limited range of operation. The utility could be confronted with either an opportunity cost when operating below the maximum operating limit or be forced to purchase power when the load increases.
- **Penalty for Not Meeting NERC Standards (CPS1 & CPS2)**